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U.S. Armed Forces. NRC Vision Committee

MINUTES AND PROCEEDINGS

of the eleventh meeting of the

ARMY - NAVY - OSRD VISION COMMITTEE

10 April 1945

National Academy of Sciences
Washington, D. C.

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U.S. Armed Forces - NRC Vision Committee

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Vision Committee files	149-175

Page 8 missing

ARMY - NAVY - OSRD VISION COMMITTEE

MINUTES

Eleventh Meeting
National Academy of Sciences
Washington, D.C.
1000, 10 April 1945

The following were present:

AAF	(M)Dr. D. W. Bronk
	(A)Lt. A. Chapanis
	Major P. R. McDonald, Office of the Air Surgeon
	Capt. Richard G. Seobee, School of Aviation Medicine, Randolph Field, Texas
AGF	Major L. O. Rostenberg, G-3 Section
Engrs	Dr. George E. Wald, Consultant, Engineer Board
Ord	(M)Lt. Col. R. S. Cranmer
	(A)Mr. John E. Darr
	Lt. Carl E. Prymila
QMG	(A)Capt. Richard M. Toucey
SG	(M)Col. Derrick T. Vail
	Col. J. F. Lieberman, Physical Standards Division
	Lt. Col. Cornelius E. Gorman
WDLO	(M)Capt. Howard E. Clements
CominCh	(A)Lt. S. H. Britt
BuAer	Lt. Harry H. Stuart, Aircraft Camouflage Section
	Ens. Brian O'Brien, Jr., Aircraft Camouflage Section
BuMed	(M)Capt. J. H. Korb
	(A)Lt. Comdr. R. H. Peckham
	Lt. Harry J. Older, Aviation Psychology Branch
BuOrd	(M)Comdr. S. S. Ballard
	(A)Lt. Nathan H. Pulling
	Lt. Ellsworth B. Cook, Harvard University
	Ens. Kenneth V. Knight, Research and Development Division
BuPers	Lt. William G. Colman, Enlisted Classification Section
	Lt. (jg) John C. Snidecor, Standards and Curriculum Division
	Ens. Kenneth E. Clark, Enlisted Classification Section
	Ens. James F. Curtis, Standards and Curriculum Division
BuShips	Lt. Comdr. R. M. Langer, Physics Research Section
I C Bd	(M)Lt. Comdr. George W. Dyson
NMRI	Lt. M. Bruce Fisher
SubBase	(M)Capt. C. W. Shilling
	Lt. Dean Farnsworth, Medical Research Department
	Lt. John Sulzman, Medical Research Department
NAS	Comdr. B. J. Wolpaw, SAM, Naval Air Station, Pensacola
	Lt. Lynn S. Beals, Naval Air Station, Quonset Pt.
	Lt. (jg) Jesse Orlansky, Naval Air Station, Quonset Pt,

NAVY ORG Dr. E. S. Lamar, Operations Research Group

OSRD NDRC (CM)Dr. F. E. Wright
APP (M)Dr. C. W. Bray
Dr. W. J. Brogden, Contractor's Technical Representative, Projects AC-94 and N-114.
Dr. John L. Kennedy, Technical Aide
Dr. Dael Wolfle, Technical Aide
CMR (M)Dr. Walter R. Miles
(CM)Dr. Selig Hecht
OSRD (M)Dr. Donald G. Marquis

Dr. Morris S. Viteles, Committee on Selection and Training of Aircraft Pilots, NRC
Mr. Edwin Ewart, Committee on Selection and Training of Aircraft Pilots, NRC
Major A. H. Neufeld, R.C.A.M.C. Liaison Office
Lt. Comdr. J. A. Powell, Canadian Joint Staff

1. The chairman called for corrections or alterations in the <u>Minutes and Proceedings</u> of the tenth meeting. There were no corrections.

The following line should be inserted at the bottom of page 17 of the Minutes and Proceedings of the sixth meeting: "never for more than 6 hours and frequently for less each day."

2. Dr. Bronk has reported that five NDRC Model III Adaptometers are available at the Johnson Foundation for any OSRD contractor who might be able to use them. It is requested that interested project directors contact Dr. Bronk.

3. Surg. Lt. Sable has forwarded the following statement concerning seasonal variation observed in night vision thresholds among Canadian Navy personnel (Proceedings, tenth meeting, p.22):

"Data are available for two bases in which during the course of the year 700 to 900 men were tested monthly. Analysis of the results shows no relation between the night vision threshold and the season of the year."

4. The following reports are published from the discussion of the NDRC binocular testing program at the tenth meeting of the committee.

A. A study of pupil size at low levels of illumination - Dr. I. H. Wagman (Minutes, tenth meeting, item 12E, p.8). 13*

B. Factors affecting night binoculars - Dr. H. K. Hartline (Minutes, tenth meeting, item 2F, p.8). 14

5. Lt. Snidecor forwarded a Bureau of Naval Personnel memorandum (NC/P-4129-EB, 4 April 1945) directed to (1) BuPers schools and (2) other schools (for information) on modification and explanation of recognition instructional procedures (Minutes, tenth meeting, item 5, p.7) 16

6. Ens. Knight, representing the Bureau of Ordnance, presented for discussion problems relating to the maximum allowable discrepancy in magnification of the two images in binoculars. 18

7. Lt. Snidecor asked for suggestions from the members of the committee concerning proper scanning procedures for sky lookouts to be formulated for a revision of the Lookout Manual (NavPers 170069). 21

8. Further investigations on tracer fire filters reported by Lt. Comdr. Peckham (Proceedings, eighth meeting, pp. 20-25). 65**

9. A statement of service needs concerning design of binoculars and telescopes prepared by Comdr. Ballard in response to request by the Vision Committee (Proceedings, tenth meeting, pp. 41-42) was distributed. Members are requested to forward comments on this statement to the Secretary's office. The Committee 22

GREED: that a subcommittee be appointed to (1) evaluate and interpret present data, (2) determine the need for further data, and (3) examine the means for securing it. (Proceedings, tenth meeting, p.42)

*Numbers at the right refer to pages in the Proceedings on which the full report or discussion is presented.

**Confidential Supplement

The chairman appointed Dr. Bray, Comdr. Ballard, Lt. Col. Cranmer, Dr. Hecht, Dr. Hartline, Dr. Dunham, and Lt. (jg) Verplanck to the sbucommittee.

10. Visual selection standards.

A. Dr. Marquis summarized present visual selection standards and distributed copies of Manual of Ocular Tests, published in 1942 by the Council on Education and Professional Guidance of the American Optometric Association.

B. Capt. Scobee discussed research on visual standards in the Army Air Forces. 24

C. Comdr. Wolpaw presented a report on visual standards in Naval aviation and reviewed some of the problems that indicate a need for an intensive study of visual requirements for aviators. 27

D. Lt. Comdr. Peckham described experimental design for testing the validity and reliability of visual screening devices. 31

E. Lt. Sulzman reported retest data obtained on visual screening tests at the Medical Research Laboratory, New London. 34

F. Dr. Viteles outlined the proposed design of a research project on analysis of the relationships between visual measures and flight performance to be carried out under the direction of the National Research Council Committee on the Selection and Training of Aircraft Pilots. 43

G. Dr. Bray summarized data from several Applied Psychology Panel projects on the reliabilities, interrelationships, and validities of visual selection tests for height finder and radar operators and stated that test reliabilities and interrelationships are low, but validities are sufficiently high in some instances to warrant practical use.

H. Lt. Farnsworth called attention to variables requiring standardization in visual examinations. 57

I. Lt. Comdr. Peckham discussed new design of acuity test object and demonstrated the Ortho-Rater and Sight-Screener which were available for examination. 61

ABSTRACTS 73**

ARMY - NAVY - OSRD VISION COMMITTEE

PROCEEDINGS

Eleventh Meeting
National Academy of Sciences
Washington, D.C.
1000, 10 April 1945

4. THE NDRC BINOCULAR TESTING PROGRAM

A. A Study of Pupil Size at Low Levels of Illumination

Dr. Irving H. Wagman

This study was undertaken in relation to the problem of the design of a proper exit pupil for night binoculars. It was done at Brown University on 10 observers who were subjects for experiments designed to test the efficiency of night binoculars. The pupil measurements were made by means of infrared photography.

The following problems were considered:

1. The average size of the eye's pupil and its range of distribution at brightness levels ranging from complete darkness to full moonlight.

The British have recently made a fairly extensive survey on naval personnel of pupil size at 8 brightness levels ranging from zero to 1 c/ft^2. Although it is important to know the average size, it is even more important to note the frequency distribution at any brightness level. The range is large. For example, at zero brightness, the smallest diameter of the 52 British observers was 5.7 mm. and the largest 9.1 mm. At 10^{-5} c/ft^2 (starlight), 69.2% of the group have a pupil size of 7.0 mm. or more; and 21.1%, 8.0 mm. or more. At 10^{-3} c/ft^2 (moonlight), the corresponding percentages are 46.2% and 9.6%. Therefore, even at moonlight, almost half the population would gain more advantage from a binocular having an 8.0 mm. exit pupil than from one having a 7.0 mm. exit pupil.

2. In comparing visibility data obtained with binoculars with that obtained by naked eye observation, the retinal illumination (the product of brightness and pupil area) must be known. Therefore, in analyzing binocular performance we must know the observer's pupil size as well as the exit pupil size of the instrument. The information

obtained on the 10 Brown observers is thus used to aid in determining the efficiency of the binoculars which they used.

3. Since variability of seeing may be influenced by variations in pupil size, we attempted to study the fluctuations of pupil size over any one period or from day to day. The pupil area variations of any one individual rarely exceeded 0.1 log unit at any one brightness level, and in most cases was well within that range. These fluctuations are much less than the range of distribution of the group as a whole. The standard deviation for any one individual was in most cases between 0.02 to 0.05 (in log area) while that of the group as a whole was about 0.1 The individual variations can be useful in evaluating the individual's visibility performance.

4. We have found that an accommodation of -1D or -2D seemingly has no significant effect on pupil size, and even -3D may have very littl effect. According to the British -4D causes a significant constriction of the pupil. Therefore, unless the binoculars are badly out of focus, there will be no appreciable effect on pupil size.

B. Factors Affecting Night Binoculars

Dr. H. K. Hartline

Final choice of the best kind of night binoculars for any given type of use can only be made after practical tests under actual operating conditions. Adequate design work, however, which must precede such tests can only be made intelligently if the physical and especially the physiological factors governing the performance of binoculars are understood. The primary purpose of the programs at Dartmouth and at Brown has been to provide empirical information as to the relation of the various design characteristics to the visibility of targets under rather idealized observing conditions. In addition, these data may be analyzed to increase our understanding of general principles affecting binocular performance.

The more obvious factors determining the performance of an observer with binoculars in detecting targets at night are magnification, exit pupil and transmission of the instrument. If these were the only factors, it would be possible to predict the ranges at which targets could be detected with binoculars from a knowledge of the observer's ability to detect them by naked eye.

Targets are seen by virtue of the difference between their brightness and that of their background. It is a convenient fact of

retinal physiology that for cases of greatest practical interest, at levels of illumination less than bright moonlight, the product of this brightness difference into the angular area subtended by the target ($\Delta B \Omega$) is the principal factor determining visibility at a given level of general background brightness (relatively independent of the area, if this is less than 10^{-4} steradians, and of the shape, if length does not exceed 5 times the width, and of the sign of ΔB - whether the target is darker or lighter than its background). The threshold value of flux increment is approximately 10^{-10} ft. ca. for a totally dark background. Four times this minimal quantity is required for targets seen against a background of the brightness of the starlit sky.

From the curve relating the quantity of light to background brightness, as determined by naked eye observations, it should be possible to calculate the ranges of visibility of objects of various sizes and contrasts when using binoculars of various magnifications. These calculations must, of course, make allowance for the transmission of the instruments and the area of exit pupil. When applied to the data collected at Dartmouth, good agreement was obtained between calculated ranges of visibility and those actually observed with 6x, 7x, and 10x binoculars. However, data from the British report NPL/scan/4 and data recently collected at Brown University show marked failure of the binoculars to provide the expected gains in visible range. For these latter data the discrepancy between observed and calculated ranges increases with magnification, and becomes discouragingly large (.4 - .7 log units of $\Delta B \Omega$) at 10x magnification.

It is scarcely to be expected that full use of optical power can be obtained with a hand-held instrument, even for mere detection of targets, and the Dartmouth results are perhaps more surprising than the others. Unless some unexpected physical or physiological factor has escaped us, it would appear that "unsteadiness of holding" of the binoculars must receive very careful consideration in designing the optimum night binoculars for service use. Laboratory analysis of such an elusive factor is difficult; practical field tests can never hope to cover the possible forms of binocular design under all possible conditions of use. Both types of study are essential. Increasing use is being made of anti-vibration mounts, alidades, accessory devices for steadying hand-held instruments and reducing observer fatigue. The optical and mechanical design of the binoculars themselves must avoid as far as possible the waste of fine optical quality that occurs because the observer cannot take full advantage of the instrument.

5. MODIFICATION AND EXPLANATION OF RECOGNITION INSTRUCTIONAL PROCEDURES

Lt. Snidecor reported that following the previous discussion of recognition and lookout training procedures (Minutes, tenth meeting, item 5, p. 7) Bureau of Naval Personnel memorandum, NC/P-4129-EB, 4 April 1945, was directed to (1) Bureau of Naval Personnel Schools and (2) other schools (for information).

1. In Recognition instruction the following general procedures shall be followed:

(a) In teaching new items the exposure time for slides in teaching and testing shall be one (1) second for planes and three (3) seconds for ships.

(b) Following successful and "comfortable" recognition by the majority of the class, one-half second slide exposures shall be used for planes and one (1) second for ships.

(c) Slide exposure periods may be gradually shortened, as deemed desirable, with the principle in mind that the majority of the students in a class shall be motivated and challenged but not discouraged by controlling slide exposure time.

(d) In the early training stages, correction and confirmation of each item shall be made after the flash exposure of each slide. For interim reviews, five slides may be shown and then confirmed with long exposures.

(e) During the presentation of new items to the class, the significant pattern of features shall be pointed out. Interesting motivating and related background information should be included.

(f) Slides and motion pictures used in testing for the assignment of grades shall be different from those used in training. Exceptions may be made to this rule when only one slide is available for an item.

2. Motion pictures shall be used as part of the regular curriculum in the following manner:

(a) Instructors shall edit available motion picture films in such a manner that brief ($2\frac{1}{2}$ - 5 minutes) excerpts are available of the planes initially presented by means of slides.

(b) Within one to three days following initial slide presentations, the same items shall be shown by means of these brief motion pictures.

(c) Unedited films shall, of course, be used where they are appropriate.

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6. MAGNIFICATION DISCREPANCY IN BINOCULAR INSTRUMENTS

Digest of Discussion:

Ens. Knight, Bureau of Ordnance, presented for discussion the following problems relating to the maximum allowable discrepancy in magnification of the two images in binoculars: (1) Does excessive fatigue occur during a four hour lookout watch when there is a size difference of 2%? (2) What is the maximum size difference allowable if binoculars are to be used indefinitely without fatigue? (3) Can significant errors of orientation occur with regard to rangefinders as a result of discrepancy in magnification of the two images? Comdr. Ballard pointed out that this problem is related to that of aniseikonia on which considerable work has been carried out. The present Navy specifications allow a 2% discrepancy in magnification between the two images in binocular instruments. It would be expensive to decrease the present tolerance and, consequently, important for the Bureau of Ordnance to know whether or not this difference is a seriously contributing cause to fatigue and error in stereoscopic judgments.

Dr. Bray reported that information obtained from studies of rangefinder and height finder operators indicate that a difference in magnification results in a distortion of the reticle field so that it is tilted. This distortion may or may not disturb judgments, but there was no observable increase or decrease in complaints as a result of magnification difference.

Capt. Scobee thought that a partial answer to this problem might be indicated by an SAM study. It was found that an average subject taking the Howard-Dolman test tends to set one or the other rod consistently forward or back. By changing the correction for refractive error for first one and then the other eye, it was determined that such a change can reverse an individual's setting on the Howard-Dolman test. The lens specification necessary to reverse the setting can be predicted; 1/4 diopter is sufficient for some individuals, 1 D is necessary for others. If the tolerance of a given individual were known, a given instrument could be adjusted for his particular requirements.

Lt. Comdr. Peckham has prepared the following summary of his discussion concerning aniseikonia.

> Measurements for aniseikonia on aviators in Pensacola in 1940 indicated that, although aniseikonia of small amount could be demonstrated in a very few aviators, no relation between flight difficulties or frequency of failure could be established. The conclusion of this research was that aniseikonia was not a matter

of great importance with respect to military aviation. The problem of the effect of aniseikonia created by binoculars, while not of exactly the same nature as the research performed in Pensacola, is not one of great difference in approach. Aniseikonia, when present, or when induced by size lenses, results in an illusion of space perception. This illusion includes distortion of the space and is said by the workers at Dartmouth to be associated with symptoms of ocular discomfort. The aniseikonic illusion occurs when a large field of view is subjected to retinal distortion, provided that other visual cues of space perception are lacking or are removed from the visual field. The use of binoculars of the type 7 x 50 permits a relatively small visual field. This field is so small that the aniseikonic illusion is rendered improbable. The degree of distortion produced by aniseikonia when all other visual spatial cues are removed, and when the visual field is entirely free from obstruction or limit, is extensive. It varies with the distance of the objects in the field of view and at a great distance has been reported by Ogle to be mathematically comparable to a rotation of nearly 90° This rotation is so improbable to perception that it does not occur in fact.

The problem of fatigue in looking through binoculars, it has been suggested, might be associated with induced aniseikonia. Continued use of binoculars for long periods would result in fatigue whether or not aniseikonia was present. Therefore, it is not possible to state the degree of inequality of images which would permit either unlimited use of binoculars without fatigue or minimal fatigue when binoculars are used for continuous periods as great as four hours.

The definition of magnification in per cent is one which must be examined closely. The present speaker is not satisfied that the unit 2% difference expressed in specifications for binoculars is directly comparable to the unit ¼% difference expressed as appreciable by Dr. Ames. Estimates of the effect of a quarter diopter shift between the two sides of binoculars upon the magnification of each field apparently vary. An estimate presented by Lt. Pulling states that a quarter diopter shift would be equivalent to .1% change in magnification. My own computation of the effect of quarter diopter shifts indicates that the change in magnification is a variable depending upon the primary position of the ocular setting. If the oculars are set for an infinite focus, the magnification shift is in the relation of 34.42° to 35° (half the angular size of the field). This can be expressed as 1½%. Similarly, the shift when the primary focus is at one-half diopter negative is .6% and at two diopters negative is .3% or a shift in the ratio 34.86° to 35°. These computations were made on the basis of thin lens optics for an ocular focal length of 27.4 millimeters, an objective focal length of 191.8 millimeters, and an objective angular field of 10°.

Capt. Scobee's suggestion that a change of image size will affect the Howard-Dolman cues is in line with the aniseikonic illusion, since the Howard-Dolman test is free from space cues other than relative size and binocular disparity. However, estimates of the meaningfulness of the aniseikonic illusion produced by the introduction of the minus lens before one eye are difficult to interpret from records of settings with this apparatus, since the apparatus is itself notoriously unreliable.

7. SKY SCANNING BY SHIPBOARD LOOKOUTS

Lt. Snidecor asked for suggestions from the members of the Committee concerning proper scanning procedures for sky lookouts to be formulated for a revision of the Lookout Manual (NavPers 170069).

After discussion the following proposed doctrine was formulated and agreed upon:

(1) For day: sweep the horizon sector with binoculars from left to right, returning from right to left on a line 5° above. Move the binoculars in 5° intervals, pausing 5 seconds at each interval. With the naked eye scan the remainder of the sector in successive sweeps 5° above the last, fixating at 10° intervals with a 1 second pause at each fixation.

(2) For night: scan with binoculars at five degree intervals pausing five seconds at each interval with five fixations around the binocular field at each stop.

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9. QUESTIONS CONCERNING DESIGN OF BINOCULARS AND TELESCOPES

Comdr. Ballard prepared the following statement in response to request by the Army-Navy-OSRD Vision Committee (Proceedings, tenth meeting, pp. 41-42).

Experiments with various types of binoculars and telescopes should be planned so as to provide answers to the following questions:

1. Which of the following binoculars are best suited for hand-held use in detecting and recognizing surface and aircraft targets at night?

   a. Standard 7x50x7.1° binocular
   b. Wide-field 7x50x10° BuAer Binocular Mark 41
   c. 9x63x5° BuOrd Binocular Mark 37
   d. 10x50x7° BuOrd Binocular Mark 36

2. What are the relative advantages of the above instruments and the following for mounted rather than hand-held use (mounted on gun directors, torpedo directors, gun mounts, target bearing transmitters, target designation equipments, etc.)?

   a. 6x50x7° BuOrd Telescope Mark 91 (binocular)
   b. 6x33x8° BuOrd Telescope Mark 60 (monocular)
   c. 10x70x7° binocular
   d. 12x60x3.3° German Binocular

The 20x120x3° Ships Binocular Mark 1 should be included for comparison.

3. How much advantage is gained by a binocular over a monocular telescope for use at night?

4. What diopter setting should be used in fixed-focus instruments which are to be used both in the daytime and at night?

5. What advantage is gained in a mounted binocular telescope by an exit pupil larger than 7 mm.?

6. Should the eyepieces of binoculars and telescopes be set at night one diopter more negative than daytime settings? What loss in range of detectability obtains at night when incorrect diopter settings are used?

7. How critical is precise interpupillary adjustment of binocular viewing instruments at night?

8. What advantages are to be gained by using special head-rests to shut out extraneous light and to position the eyes correctly?

9. What loss in range of detectability at night is produced by the use of a dimly-lit crossline?

10. What are the contrast sensitivities and resolving powers of the dark adapted eye across the field of vision?

Results for both stationary and rolling platforms are desired; for the latter a 5° roll with a 12-second period is suggested. It should be borne in mind that naval instruments must effect a compromise among the optimum characteristics for various levels of external illumination, visibility, and target contrast.

Although primary emphasis should be placed on field investigations of these problems, I realize that some phases of many of them can be more easily and perhaps more profitably studied with laboratory set-ups.

Although each of the above problems is of practical, "every-day" importance, they have been arranged in order of their approximate priority; academic items of borderline applicability have been purposely omitted. Our present feeling is that the desire to obtain precise and complete data on each of these problems should be subordinated to the practical necessity of obtaining partially complete and approximate information which can be put to immediate use.

Although we are desirous of assisting in every way possible, I feel that the responsibility for organizing and carrying out the proposed investigations should be assigned elsewhere. Furthermore, I am of the opinion that the problems of this study are of such paramount importance as to merit the establishment of a standing subcommittee with a nucleus of temporarily full-time personnel.

Discussion:

Lt. Col. Cranmer stated that the questions are of interest to Army Ordnance in approximately the same order, except that Item 2 is not an Army problem. Item 1 should be modified to include low contrast terrestrial targets by day or night. Instrument (a) (7x50) is of principal interest, but two new observing devices T131 (15x) and T132 (20x) will be available for testing in a few months.

Members are requested to forward comments on Comdr. Ballard's statement to the Secretary's office.

Comdr. Ballard stressed the need for a small working committee to consider the problems outlined above, and especially to make a recommendation concerning the advisability of a field test program.

10. VISUAL SELECTION STANDARDS

B. Research on Visual Standards in the Army Air Forces

Capt. Richard G. Scobee

A. Visual Acuity. The average visual acuity testing chart of today has gotten away entirely from the original principles of Snellen. The AO Project-O-Chart does not even use Snellen letters but a block type of letter without serifs. It is obvious that the letters of the alphabet are of varying difficulty. Snellen letters present a more nearly equal visual task but still vary among themselves in difficulty over a fairly wide range. Many letters of the alphabet cannot be constructed on Snellen's principles and hence should be omitted from any "Snellen chart".

In the investigations at the AAF School of Aviation Medicine those letters of the alphabet which could be constructed along strict Snellen principles were used, and their relative difficulty was determined by three different methods. Two groups, each containing six or seven letters, were finally selected. One group is, according to the statisticians, of statistically homogeneous difficulty and contains the letters K, N, G, S, Y, and P. The second group was selected for equal difficulty but on the basis of clinical trial-and-error type procedure; this second group is made up of N, P, V, O, E, and C. Two visual acuity charts have been constructed, one on the basis of each group of letters. Letter sizes begin at 20/40 and extend through 20/5, the decrement being one unit for each letter, i.e., 20/40, 20/39, 20/38, 20/37... ...20/7, 20/6, and 20/5.

Tests for reliability are being conducted on both charts at the present time. Several different scoring methods will be tried. It is tentatively planned to score the subjects on either the number of letters called correctly up to the first error (36 letters in all) or on the number of letters left to be read at the point of the first error. It is hoped that a simple conversion scheme for changing such scores to Snellen type notations can be found.

Such a system, if successful, would have the primary advantage of giving visual recordings such as 20/11 or 20/16 rather than 20/15 - 3 or 20/20 + 2. It is readily recognized that Snellen letters are not the ideal visual test object by any means, but familiarity of subjects with requirements of such a test as compared with broken circles or dotted checkerboards nevertheless would seem to make it the test of choice for large groups of men particularly when tested by a large number of examiners of varying experience. It is also recognized fully that a

large portion of the problem of visual acuity testing could be solved by adequate standardization of testing techniques and equipment.

The Committee for the Selection and Training of Aircraft Pilots is planning to carry out a study of visual acuity in relation to ability to learn to fly. This will be done at Ohio State University and details will be given by Dr. Viteles. The AAF School of Aviation Medicine is looking forward with a great deal of interest to participating in this program.

B. Muscle Balance. The work on muscle balance is summarized in the following AAF School of Aviation Medicine Reports:

(1) #139 (2 November 1944). An Analysis of the Ophthalmic Portion of the "64" Examination. (a) Muscle Balance.
(2) #298 (18 July 1944). The Effect of Exhaustion and Moderate Anoxia on Muscle Balance.
(3) #322 (21 December 1944). A Filter for the Red Lens Test in the "64" Examination.

C. Depth Perception. Whether or not normal binocular depth perception is absolutely essential for flying has never been determined. It would seem that good depth perception is essential to flying but this has never been proved.

The Howard-Dolman test of depth perception has been criticized on the grounds that it is not reliable, i.e., a subject might score 3 on one trial and 23 on the next. A fact not often considered, however, is that subjects who fail the test on one trial usually fail a second trial provided the testing conditions are standardized. Similarly, subjects who pass on one trial usually pass on a second trial. In other words, the pass-fail reliability of the test is fairly good.

Two AAF School of Aviation Medicine Reports on depth perception are of interest.

(1) #59 (1 July 1942). Comparison of Howard-Dolman Depth Perception Test, Wulfeck Group Test of Stereo Acuity, and Keystone Depth Perception Apparatus.

(2) #238 (10 February 1944). A Comparison of Three Tests of Depth Perception.

D. General Considerations. There is not a single item in the ophthalmic portion of either the Army Air Forces or Navy physical examination for flying that is foolproof. And yet, taken all in all -- each item with its weaknesses -- they make a surprisingly adequate

screening test. To cite one example, the applicant with low-grade myopia may squint his way through the test or tests of visual acuity, pass the muscle balance examination, and yet fail on the Howard-Dolman test because of his myopia. There are many cases picked up by the examination for flying which should be, and are, waivered and justly so. There are plenty of excellent fliers today who had a waiver for some part of the ophthalmic section of the flying examination.

Discussion:

Lt. Col. Fitts pointed out that in a recent study no correlation was found between the Howard-Dolman and the Stromberg tests of distance perception.

Dr. Miles asked for Capt. Scobee's opinion regarding the usefulness of various test objects for visual acuity tests. Capt. Scobee thought that although the Landolt ring had been selected as the international test object, its effectiveness is curtailed because it makes a dull test. The "E" in four positions has the disadvantage of giving clues to subjects with low-grade astigmatism. The American Optical Company Project-O-Chart does not have letters of equal difficulty. The checkerboard test object of the Ortho-Rater is satisfactory as a test for visual acuity, but the AAF School of Aviation Medicine does not consider the tests for phorias, depth perception, and color vision as satisfactory.

Col. Vail commented on testing problems in the Office of the Surgeon General. The Physical Standards Committee found that in testing candidates for West Point, a certain number of cases who fail as a result of myopia have been able to pass a retest after treatment by certain optometrists. It is thought that these subjects have been trained to recognize clues given by letters on the standard Snellen chart. A retest employing Landolt ring test objects has been given to these men, but the results have not been reported.

Dr. Bray pointed out that substituting another standard test object does not eliminate the problem of learning. The Landolt ring may be less susceptible to learning, however. Lt. Comdr. Peckham stated that a temporary reduction of myopia is possible through training by prism exercises. Capt. Scobee emphasized the effectiveness of concentrating attention on the test object as a factor in improving test scores by orthoptic training.

Col. Vail expressed an interest in the suggestion that visual standards for various military specialties be related to an analysis of the visual requirements necessary to the work to be performed.

C. Visual Standards in Aviation

Comdr. B. J. Wolpaw

The present flight physical examination employed by the Navy dates back almost 22 years. The ocular portion was developed by a group of outstanding ophthalmologists as members of the National Research Council. These eye physicians were well beyond middle life. One can well imagine that a physician over 50 years of age in 1920 had probably never been in an airplane. This new method of travel was still a mystery and surely, thought these physicians, anyone qualified to operate this terrifying instrument must be a perfect or nearly perfect physical specimen. The standards were developed, then, more on the assumption by these physicians of what they thought an aviator must be, rather than on any scientific evidence as to how much heterophoria a pilot may have and still operate a plane safely. The long number of years since the present examination was established warrants a study of the visual requirements in the light of present day avaition.

It will be of interest to review, briefly, some of the problems that have come to our attention. While checking the measurements of some optical instruments, we noted, frequently, the fact that an optical instrument loses its effectiveness as far as stereoscopic vision is concerned if the base line is less than 60 mm. This made us wonder why, if true for an optical instrument, the same might not be true in man. For a period of three months every cadet who had been dropped from training because of difficulty in flying was examined. We were surprised to find that 7 of the 35 men who failed had an interpupillary distance of 60 mm. or less. When checked on the Howard-Dolman Test and the Keystone and Verhoeff stereoscopes, these men did poorly on the Keystone and Verhoeff instruments, but were able to pass the Howard-Dolman Test. We then surveyed 600 Form I's of cadets going through training at the same time. There still appeared to be a significant difference in the number of men who had a small interpupillary distance and who washed out, as against those who completed the training. On discussing this observation with Dr. Walter Miles, he pointed out that the important factor might not be the effect of a small interpupillary distance on depth perception as much as it might be the type of individual. He felt that the individual with a narrow interpupillary distance tends to be a certain type - the thin, hypertonic individual, who may be unsuited for flight training. As we repeatedly had cadets come in with a narrow interpupillary distance and had listened to their stories of difficulties in flying, we were impressed by the possibility that the study of some such relationship might be worth while.

Observing that some men did not have 20/20 vision in each eye, uncorrected, and that of this group many did not have corrective

lenses, we felt that it would be of interest to note the effect of this factor on their performance in flying. A total of 654 men were checked. Of this group, 5.2% had vision of less than 20/20 in at least one eye. These men flew without corrective lenses. In this group of men, 17.2% of those who appeared before the Commandant's Advisory Board had vision under 20/20. Thus we see that 5.2% of the total had poor vision and that 17.2% of those in trouble had less than 20/20 vision. The complaints of these men were; inability to see the wind sock, inability to recognize strange landing fields, and poor visibility of the runway edges. The number of men checked was not great enough to permit us to decide what constitutes safe vision for military flying. We say military because, with the speed of present day planes, one or two seconds may make the difference between who shoots first and the one who does not live to fly again. We are certain that, particularly from dusk to dawn when the pilot's pupils are dilated, visual acuity drops; hence, our daytime standard cannot be reduced without a comparable further loss in acuity at night.

Our predecessors worried about the probability of pilots developing diplopia during anoxia and, hence, set what they thought were safe limits for heterophorias. Their research work was carried out, chiefly, by producing anoxia with the Henderson Rebreather and noting the effect on muscle balance. In order to check this, a phorometer was installed in a low pressure chamber and a series of tests was run, first doing the muscle balance at sea level and then at 18,000 feet. The subjects were maintained at 18,000 feet for 10 minutes without oxygen before the muscle balance was measured again. In no instance was diplopia produced. There was only one significant change in the heterophoria. Out of 20 subjects tested, one had an exophoria of 4 prism diopters at sea level and 6 prism diopters at 18,000 feet. He had 3 diopters of myopia, and in such individuals convergence insufficiencies are not uncommon. This same type of experiment was carried out more recently at Randolph Field and similar results were obtained, i.e., anoxia does not produce a significant change in the muscle balance. Only two instances of diplopia have occurred during mild anoxia at Pensacola in the past two years. In each instance the cadet had a paresis of an ocular muscle.

It was demonstrated in 1918 by Wilmer and Berens[1] that at 20,000 feet there was no change in the ability to distinguish between the Stilling plates. These authors state that, "normal color vision is considered a requisite for a good pilot". However, no one has determined what constitutes normal color vision for a good pilot. What are the problems of color vision in aviation? Between what colors must a good aviator be able to discriminate? These questions are still unanswered 26 years later.

In 1919, Capt. H. S. Howard[2] of the U. S. Army Medical Corps first described the Howard-Dolman test for binocular stereoscopic vision. This test depends upon parallactic angles and retinal disparity.

He assumed that a normal person could discriminate a parallactic angle of 8 seconds of arc. On the basis of this angle it was determined that an individual with an average interpupillary distance and normal stereoscopic vision should be able to approximate the two sticks on the test apparatus to within 30 mm. of each other. It was recently shown by Imus[3] that in a carefully conducted series of tests on the same individuals there are differences in the scores obtained depending upon whether the movable stick is started behind the fixed stick and moved forwards, or is started in front and moved backwards, or whether the subjects are allowed to jockey the movable stick back and forth. This test also allows an individual with monocular vision to pass by a careful comparison of the relative width of the two sticks. We are unable to find any report of an accurate study to determine what degree of stereoscopic vision is necessary for a good aviator. Once this factor is known, it would be possible to devise a test to determine this degree of depth perception with less possibility for error than exists now with the Howard-Dolman Test.

The last critical study carried out on experienced aviators was that of Capt. J. C. Adams[4] in 1928. In examining one hundred men who had been flying for more than two years, Captain Adams found that many could no longer pass the tests. There appeared to be an increase in exophoria with the passing of years so that it was necessary to obtain waivers on 7% of those examined because of excessive exophoria. Yet these officers were successful aviators. It is time that this type of evaluation of the flight physical examination be carried out again. We feel that it would be of value to examine several hundred aviators who have just returned from active combat duty, especially carrier duty, and to study the results in a manner similar to that done by Capt. Adams.

The problems presented herewith indicate the need for an intensive study of the visual requirements for a naval aviator. We need an examination that has a high test-retest reliability as well as validity.

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2. Howard, H. J., A six-meter stereoscope. Am. J. Ophthal. 1919, December.
3. Imus, H. A., Comparison of Ortho-Rater with Clinical Ophthalmic Examination. Project X-499 (Av-268-p) U. S. Navy
4. Adams, J. C., The physical examination for flying with special reference to the eyes. U. S. Naval Medical Bulletin, 1928, October.

Discussion:

Dr. Bronk called attention to Dr. Hecht's project on the testing of color vision in relation to the color requirements of the Army and Navy (Contract OEMcmr-289) and to the report by Dr. Hecht, Captain Wallace, and Captain Hexter, "Color Vision and Its Relation to the Detection of Camouflage." Psychological Section, Office of the Air Surgeon, Research Bulletin Hq. 43-6, 14 October 1943.

Dr. Bray commented on the large proportion of men who were found by Comdr. Wolpaw to have an interpupillary distance of less than 60 mm. He suggested that since it is difficult to find this proportion (10%+) in the ground and service forces that some special factor must be operating. Dr. Brogden thought that the method of measuring interpupillary distance, in this case by millimeter rule, might have influenced the results. Lt. Farnsworth pointed out that the plastic now used for transparent millimeter rules is subject to shrinkage.

Dr. Bronk asked if different visual standards are necessary for one who is about to learn to fly than for one who has already learned. Comdr. Wolpaw stated that a higher standard is necessary when learning, but it can be lowered after a man has learned to fly.

Dr. Bray criticized the tendency to determine the visual requirements of a job by the characteristics of a successful group. There is no easy substitute for the procedure of checking the validity of predictions based on tests administered prior to training.

In response to request by Dr. Marquis, Ens. Curtis described a study in which a group of successful gunners (six months or more experience) were measured on the Ortho-Rater. Their scores were compared with present standards established for the Ortho-Rater and with results for a group representing the general Navy population. Over 50% of the successful gunners failed to meet present standards, and, except for color vision, there was no difference between this group of gunners and the unselected group.

Lt. Chapanis emphasized the importance of the quality of transparent material to good vision for aviators. A group of approximately homogeneous and better than average subjects were given the Howard-Dolman test (made fairly reliable at the Aero Medical Laboratory) and then retested while viewing through a piece of glass. The error scores were increased as much as ten times.

D. Validity and Reliability of Vision Screening Devices

Lt. Comdr. R. H. Peckham

The use of visual screening tests, such as the Ortho-Rater prepared by the Bausch and Lomb Optical Company, the Telebinocular prepared by the Keystone Company, and the Sight Screener prepared by the American Optical Company, frequently results in conflict of opinion or fact when compared with clinical tests. The difficulties seem to be resolvable into three types:

(1) inadequacies of the screening devices,
(2) inadequacies of the clinical tests,
(3) application of screening measurements to ophthalmic diagnosis.

The difficulties of type (1) are associated with unreliability of the screening device. Difficulties of type (2) seem to be associated with lack of validity of the screening device coupled with unreliability of the clinical test. Difficulties of type (3) are due to either the logical acceptance by the opththalmologist of screening device scores in lieu of less reliable clinical methods, or the application of screening device scores to diagnosis by lay personnel, who should not be permitted to resolve the measurements afforded by screening devices into diagnostic decision.

It is the purpose of the present Navy research to attempt the solution of these three difficulties. The clinical tests, which are prime criteria, and upon which qualified persons will make diagnoses, must be examined for reliability, and improved if found inadequate. The screening devices must be examined for reliability, and then compared for validity to the clinical tests. Following these studies, procedures which provide adequate application of the screening devices without unauthorized diagnosis must be established.

A general schema which seems to approach these requirements has been devised. It has been considered, first, that clinical requirements have been set by regulation, and that, until the regulation is changed, the validity of the clinical test must be considered unassailable for immediate screening purposes. Secondly, it has been considered desirable to divide an unselected population, by means of a screening test, into three, rather than two, classes:

(1) Personnel certain of passing clinical standards.
(2) Personnel certain of failing clinical standards.
(3) Personnel so near the clinical standard that they must be examined by qualified officers who are authorized to make a diagnosis.

By rejecting the worse applicants, and by screening out the faultless applicants, it is believed that the examining officer will have more leisure to examine carefully borderline applicants.

Thirdly, a set of passing and rejection scores must be set up, which perform adequately with respect to reliability of the clinical test, validity of the screening test with reference to the clinical test, and reliability of the screening test.

To select such scores it is necessary to measure a group of men twice each on both the clinical and the screening tests. These measurements are then to be placed in scattergrams as in Figures 1, 2, and 3, and critical scores can be selected.

Figure 1 - Reliability of clinical test.

Point A represents pass-fail score established by regulation. Point B is chosen so that no failures are found above AB'. Point C is chosen so that no failures are found below C'D. Cases falling from B to C require clinical judgment or diagnosis.

Figure 2 - Validity of screening test.

Point E is chosen so that no failures or doubtful cases fall to the right of E'B. Point F is chosen so that no passers or doubtful cases fall to the left of F'G.

Figure 3 - Reliability of screening test.

Point H is chosen so that no passing or doubtful cases fall to the left of H'J. Point I is chosen so that no failing or doubtful cases fall to the right of II'. Cases from zero to H are certain failures. Cases from I to perfect are certain passers. Cases from H to I must be re-examined by a qualified officer. The screening test can therefore be administered by corpsmen, who do not have to make any questionable decisions or diagnoses.

The estimation of coefficients of correlation is not required for this approach. A high sorrelation, if demonstrable, would indicate the degree of risk involved in moving points B and H to the right, or points C and I to the left, beyond the actual limits of the scattergram. Since this may prove useful, the product-moment correlation might be computed about the point B', C', H' and I'. An estimation of the adequacy of the sampling might be established by the use of X^2. However, the prime criterion remains concerned only with the direct examination of the scattergram.

This procedure has been applied to data taken by Lt. H. A. Imus, H(S) USNR, at NAS, Pensacola, Fla. His data indicated, with

respect to visual acuity selection, that the clinical test was so unreliable, as well as the Ortho-Rater, that very little screening would have been possible. The study of Ortho-Rater scores for stereopsis showed that the Ortho-Rater was moderately reliable but that the Howard-Dolman scores could not predict themselves, and that, therefore, no screening for the Howard-Dolman test could be anticipated.

This schema will be used by the Navy for visual acuity, stereopsis, and phoria screening, and the results will be presented to this Committee at a later meeting.

Figure 1

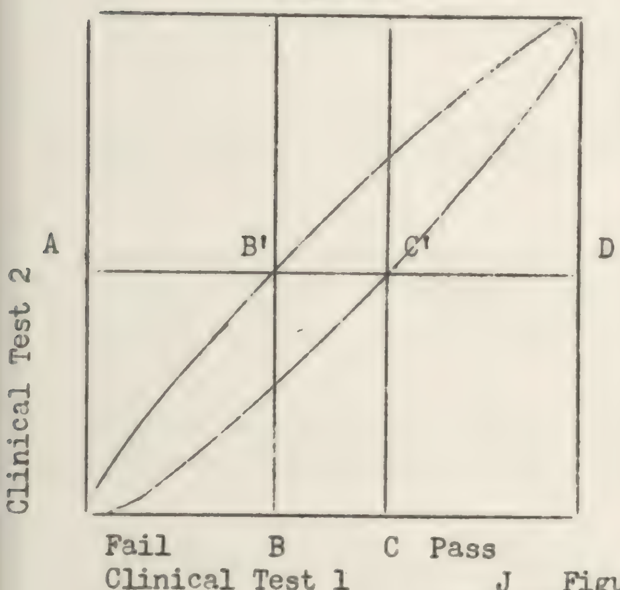


Figure 2

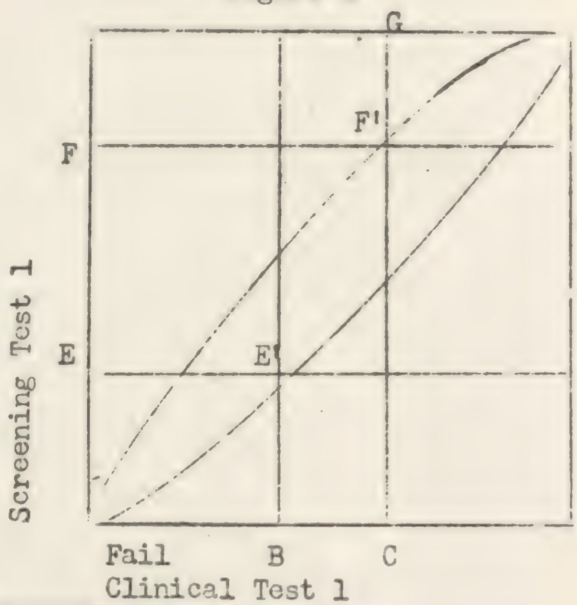
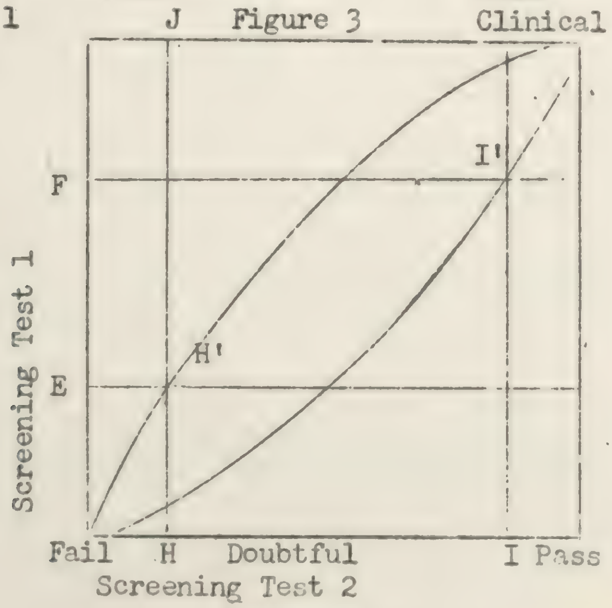


Figure 3



E. Comparison of Five Methods of Screening for Acuity and Muscle Balance

The following report was prepared by Lt. John H. Sulzman, Lt. Dean Farnsworth, Lt. (jg) Neil Bartlett, and Mary I. Kinared, Y3c, and was presented by Lt. Sulzman.

I. Summary.

(1) Forty Naval personnel were tested and retested for visual acuity and for muscle balance using five methods.

(2) Of the five methods studied, the Telebinocular shows least promise as a visual screening device for determining visual acuity.

(3) The Sight Screener was a preliminary model with too many defects in the test targets for recommendation in its present form. It is, however, mechanically satisfactory.

(4) The Ortho-Rater tests for visual acuity and for muscle balance proved generally satisfactory. Retests with this device show its reliability is comparable with that for clinical tests. In addition, the tests are simple and easily administered.

(5) Contrary to expectations, the use of more accurate Snellen charts, at both distance and near, by instructed personnel yielded surprisingly consistent results.

(6) Correlation studies indicate that the Ortho-Rater and the improved Snellen charts measure approximately the same functions. Their ability to predict retest scores was of the same consistency as their ability to predict scores between themselves.

(7) All methods used for testing vertical phoria showed comparable scores on retest.

(8) The Telebinocular yielded scores for far lateral phoria which are more reliable than those obtained with other methods used.

II. Introduction.

At the Medical Research Department of the U. S. Submarine Base, New London, Conn., a study has been initiated for the purpose of comparing certain visual screening devices with clinical visual tests.

Answers to two questions are sought: (a) Does each screening

device yield reliable results so that comparable scores are obtained on retest? (b) How well do scores obtained by the use of such screening devices compare with the results of clinical tests? The present report is only preliminary, since the complete procedure has not yet been applied to a sufficiently large number of individuals.

III. Description of Tests and Procedures.

Three visual screening devices, the Telebinocular, the Ortho-Rater, and the Sight Screener, were employed. A testing schedule was arranged so that each individual was tested and later retested in one day on each of the devices and with clinical testing methods. The sequence of tests and retests was varied in the schedule for each day.

All tests were given in the soundest possible routine manner. Determinations of visual acuity by the use of Snellen charts for distance and near were made by pharmacist's mates especially instructed in this method. Clinical tests for muscle imbalance were performed by an ophthalmologist. Visual screening devices were operated by Waves instructed to a satisfactory level of skill in their use.

All subjects were measured without glasses. Scores were turned in as soon as they were recorded, so that no tester had knowledge of the scores obtained either by any other method or by previous tests using the same method. Since the right eye was tested first in each instance, the score obtained for each individual's right eye might be affected by unfamiliarity with the given test. For this reason only the scores for the left eye were used when comparisons were made. When comparing one test with another, the first score for the left eye was always used.

For comparison of data, all scores for visual acuity were reduced to the decimal notation (20/20 = 1.0; 20/100 = 0.2, etc.).

A. Clinical Procedures:

(1) Snellen letters at 20 feet. Accurately reproduced Snellen letters equated in difficulty, and graduated in steps of even-numbered decimal values are shown in a twenty-foot range whose blank walls are painted a medium gray. The letters are illuminated uniformly to a brightness of 15 apparent foot-candles. Separate charts are used for each eye. In scoring, each individual was given credit for reading a line if he misnamed one letter on that line; if he erred on two letters the line was considered missed.

(2) Maddox-rod Screen Test at 20 feet. This standard procedure combines the Maddox-rod test and the cover test. A Risley rotary prism is used to determine the amount of lateral phoria, and a Stevens Phorometer is employed to measure the amount of vertical imbalance.

(3) American Optical Co. "Project-O-Chart" at 20 feet. This is a method frequently used in measuring distant visual acuity. It involves the projection of lantern slides of Snellen letters on a screen. The illumination varies with the distance from the projector, but as used in this study the brightness of the screen was 22 apparent foot-candles.

(4) Snellen letters at 13 inches. This is similar to the distance test as to choice and reproduction of letters. The score is graduated in the same intervals, again using decimal notation. Separate letter cards are used for each eye; each letter subtends 5 minutes of visual angle and each stroke subtends one minute at 13 inches distance. The brightness of the chart used in this study was measured at 18 apparent foot-candles.

B. Visual Screening Devices.

(1) Keystone "Telebinocular". This is perhaps best described as a modification of the Brewster stereoscope with stand, attached movable slide holder, and light. Since many testing slides are available, it was decided to employ the "dot" type of target for visual acuity as found on Keystone slides DB-1B, DB-2B, and DB-3B. In determining muscle balance, slide DB-9 was used for measuring lateral phoria and slide DB-8C for vertical phoria. Illumination was uncontrolled and may vary greatly, but as measured during this study, was somewhat under 50 apparent foot-candles on the targets.

(2) Bausch and Lomb "Ortho-Rater". This instrument employs the stereoscopic principle with optical equivalents for far and near distances. The targets for right and left eyes are mounted side by side on drums, and are illuminated from behind at an average brightness of about 230 apparent foot-candles. The "distance" drum tests: (a) vertical phoria; (b) lateral phoria; (c) binocular acuity; (d) right acuity; (e) left acuity; (f) depth perception; and (g) color perception. The "near" drum tests: (a) binocular acuity; (b) right acuity; (c) left acuity; (d) vertical phoria; and (e) lateral phoria.

Visual acuity is measured by determining the position of a black and white "checkerboard" in any one of four possible positions on targets which are graduated in size. Scores of 1 to 15 represent acuity of 0.1 to 1.5 in the decimal notation.

(3) American Optical Co. "Sight Screener". This instrument employs the stereoscopic principle at the optical equivalent for distance; near vision is tested without the interposition of lenses. The targets for right and left eyes are superimposed on Polaroid vectograph film. The brighter targets are illuminated from

behind so that a brightness of about 20 apparent foot-candles is obtained. The dimmer targets were estimated to have a brightness of 1 apparent foot-candle.

This instrument employs the same target for the optical equivalent for distance and near for each visual function, but at a greater angle below the horizontal when testing for near. The visual functions tested are: (a) superimposition and abduction; (b) depth perception; (c) right acuity; (d) left acuity; (e) binocular acuity; (f) vertical phoria; and (g) horizontal phoria. The acuity target is a broken circle which is of uniform size throughout. The "break", which may appear in one or two of four possible positions, is graduated in logarithmic steps.

Treatment of Data

The raw data from the group of 40 observers tested by all methods were plotted on scatter diagrams, and were given brief statistical treatment with consideration for the small sample of the population tested. The diagrams, and information obtained therefrom, are included in this report as Tables I and II and Plates I, II, and III.

Data from larger groups previously tested are included in Column 1 of the tables for comparison of reliabilities with the smaller samples.

The percentages of scores which were identical on test and retest were used as one measure of reliability. These percentages are found in Column 2 of Tables I and II.

Another arbitrary measure of retest reliability was applied. Scores on retest which fell within one class interval of the first test score were taken to be within tolerable limits. The percentages of retest scores which fell within these allowed limits are given in the third column of Tables I and II.

The data with greatest apparent promise were subjected to further statistical analysis. A Pearson coefficient of correlation was determined for these tests and is found in Column 4.

To determine the ability of the tests to predict pass-fail scores, the data were examined and tabulated in terms of pass or fail on each test and retest. Beneath each scattergram, the corresponding 4-way pass-fail table has been placed.

TABLE I

SUMMARY OF TEST-RETEST DATA

VISUAL ACUITY

Type of test	No. of observers	Percentage with identical retest score	Percentage within allowed retest limits	Pearson r
Telebinocular - far acuity	40	52.5	70	
Snellen letters on 20' range	141	49	90	
Snellen letters on 20' range	40	60	97.5	0.94
Ortho-Rater - far acuity	121	56.2	95	
Ortho-Rater - far acuity	40	50	95	0.84
Sight Screener - far acuity	75	85.3	92	
Sight Screener - far acuity	40	82.5	90	
Project-O-Chart - far acuity	154	58.4	85.7	
Project-O-Chart - far acuity	40	57.5	92.5	
Snellen letters at 13"	40	57.5	92.5	0.88
Ortho-Rater - near acuity	121	64.5	95	
Ortho-Rater - near acuity	40	65	92.5	0.77
Sight Screener - near acuity	75	84	93.3	
Sight Screener - near acuity	40	72.5	87.5	
MUSCLE BALANCE				
Far vertical phoria				
Maddox-rod Screen	40	62.5	85	
Ortho-Rater	40	60	95	
Sight Screener	40	75	92.5	
Telebinocular	40	97.5	97.5	
Far lateral phoria				
Maddox-rod Screen	40	22.5	67.5	
Sight Screener	40	47.5	62.5	
Ortho-Rater	40	30	57.5	
Telebinocular	40	45	92.5	

TABLE II

SUMMARY OF INTER-TEST COMPARISONS

Type of test	No. of observers	Percentage with identical retest score	Percentage within allowed retest limits	Pearson r
VISUAL ACUITY - FAR				
Ortho-Rater, far acuity, vs Snellen letters 20'	40	27.5	75	0.77
Sight Screener, far acuity vs Snellen letters 20'	40	2.5	10	
Telebinocular, far acuity vs Snellen letters 20'	40	20	60	
VISUAL ACUITY - NEAR				
Ortho-Rater, near acuity, vs Snellen letters 13"	40	32.5	85	0.75
Sight Screener, near acuity, vs Snellen letters 13"	40	0	5	

IV. Observations and Criticisms.

From this preliminary study of a small series of cases, the following observations and criticisms are made:

(1) Certain limitations of clinical charts in current use for testing visual acuity should be noted: (a) Such charts vary in the gradations of size intervals (20/120, 20/80, 20/25, etc.); (b) the scoring of results obtained by the use of Snellen charts is subject to individual interpretation of the number of letters missed in each line (20/30 + 3, 20/20 - 3, etc.); (c) gross imperfections in the printing of clinical charts for visual acuity have the effect of yielding different values for corresponding lines on different charts; and (d) scores for visual acuity vary with the intensity of illumination.

(2) The results of clinical tests demonstrate that they are no more reliable than other tests; in some cases they are less reliable.

(3) Visual screening devices are apparently as reliable, or can be made as reliable, as clinical methods for the determination of visual acuity; in some cases they are already more reliable. Certain weaknesses which were apparent in the Telebinocular and Sight Screener may be correctible with more adequate targets.

(4) The Ortho-Rater seems to predict clinical test data for far and for near visual acuity better than do other screening devices.

(5) The Sight Screener scores for visual acuity have a distribution weighted at the extremes. A few individuals make very low scores, and most individuals obtain the maximum score.

Muscle Balance

Clinical experience derived from tests of muscle balance has taught that this visual function is a complex integration of voluntary and reflex variables.

(6) All three screening devices seem to be more reliable than the clinical test in the determination of vertical phoria for distance. However, for the Sight Screener and Telebinocular, this reliability was partially the result of their insensitivity. Because there are no marked variations in the data for vertical phoria, illustrations have been omitted.

(7) The clinical test for lateral phoria appears slightly more reliable than the Ortho-Rater. The distributions for both accord with the ophthalmologic experience with a population. The distribution

for the Telebinocular appears somewhat similar, but since the interval steps in prism diopters are not known, no conclusion can be drawn beyond that of self-reliability. There is evidently some feature in the construction of the Sight Screener which imposes a spurious stability of the optic axes at one scale point; the loaded distribution at the orthophoric position does not accord with clinical experience.

It is suggestive that the tests which show the most extended range of scores (e.g., the Maddox-rod). employ the widest visual fields; the tests which show the most limited score range (e.g., the Sight Screener) employ the most restricted visual fields.

(8) The scores obtained with the Ortho-Rater permit measurement of esophoria to a maximum of only 6 1/2 prism diopters. Military requirements ask for a determination of scores in excess of ten prism diopters.

(9) The Sight Screener targets for muscle imbalance are illuminated too dimly to permit all persons to identify scale markings in the test. Thus, in the test for vertical phoria, three individuals were unable to identify the scale markings, and in the test for lateral phoria, eleven persons.

(10) No one visual screening device demonstrates superior reliability over other methods in all respects.

(11) The Ortho-Rater is commended for standardization of procedure and ease of administration. The Sight Screener is commended for facility of mechanical operation. The Telebinocular is commended for simplicity of construction.

V. Recommendations.

Pending the results of further study, the following recommendations are made:

(1) Clinical cards for visual acuity testing should be standardized for use by the Navy. (a) Acuity units in terms of distance should be graded in steps of uniform differences from line to line, and in measures of difficulty which will be comparable with present systems. (b) Test letters should be reproduced precisely in order to eliminate present inaccuracy in printing. (c) The procedure for conducting tests for visual acuity should be specified uniformly for all Naval personnel. Partial scores should be omitted. (d) Several interchangeable cards of equal difficulty should be provided so that separate letter cards will be used for each eye, and more than one alternative card will be available for doubtful cases.

(2) A test card cabinet with even and standardized illumination upon the letters should be specified for use wherever visual acuity is determined either for distance or near.

(3) A specified course of training should be prescribed for the personnel who will administer any or all types of visual tests. The curriculum for such a course should be patterned along lines of instruction which are available at certain institutions.

(4) Targets employed in visual screening devices and the present models of such devices should be perfected in the interests of accuracy, standardization, compactness, and ease of administration throughout the Navy.

(5) The development of visual screening devices should be encouraged. The achievement of accurate screening devices has implications which the Navy should exploit.

<u>Discussion:</u>

Comdr. Wolpaw pointed out that the Sight Screener has an adduction test while the Ortho-Rater has not. If the adduction test were given before the test for lateral phoria on the Ortho-Rater, the results might be affected. Lt. Sulzman thought that since several tests precede the test for lateral phoria on the Ortho-Rater, it seems likely that the eyes will have resumed a position of rest.

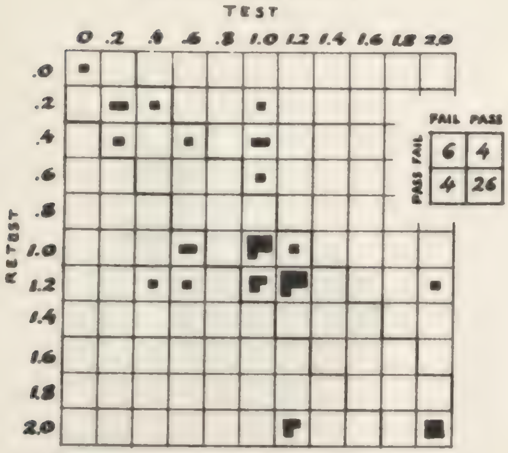
Capt. Scobee objected to a screening test for phoria. He thought it unlikely that it would be possible to develop a good screening test set for infinity because of an "awareness of near reflex." A study comparing clinical tests for phoria at near and far range shows a low correlation between different tests at the 13-inch distance.

Dr. Hecht emphasized the importance of adequate brightness for any visual test and suggested that no test should be administered at less than 15-20 foot lamberts.

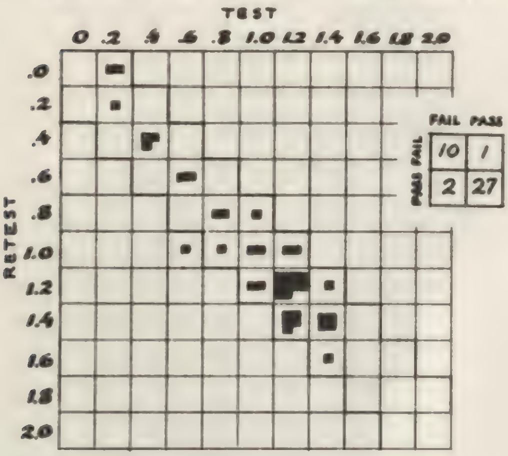
PLATE I

Test-Retests for FAR ACUITY ~ ~ left eye ~ 40 cases

TELEBINOCULAR

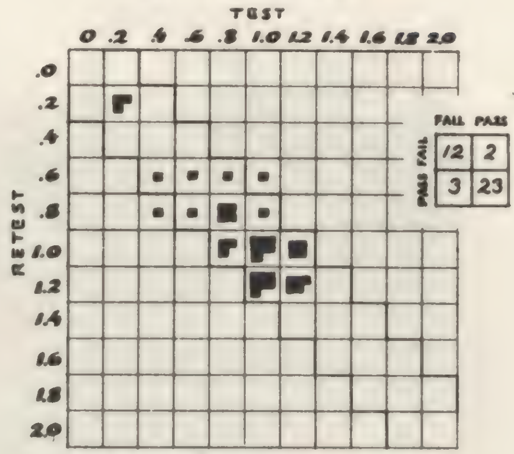


SNELLEN LETTERS - 20 *foot range*



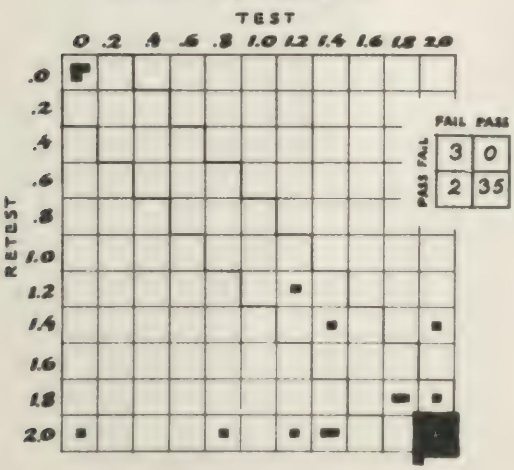
TEST Mean = .995, σ = .362 RETEST Mean = 1.02, σ = .402 r = 0.94

ORTHO-RATER



TEST Mean = .895, σ = .283 RETEST Mean = .925, σ = .278 r = 0.84

SIGHT SCREENER



PROJECT-O-CHART

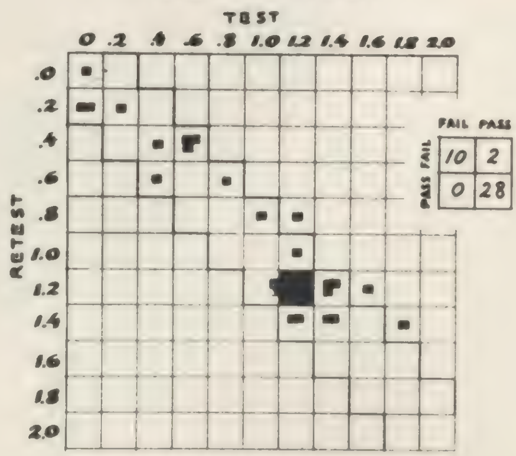
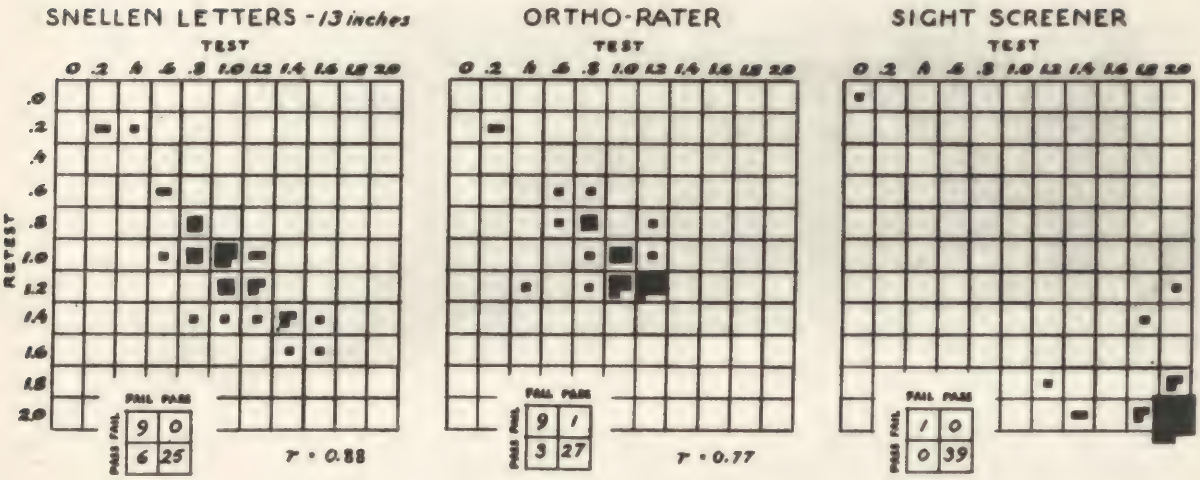


PLATE II

Test-Retests for NEAR ACUITY - left eye - 40 cases



Test-Retests for LATERAL PHORIA - 40 cases

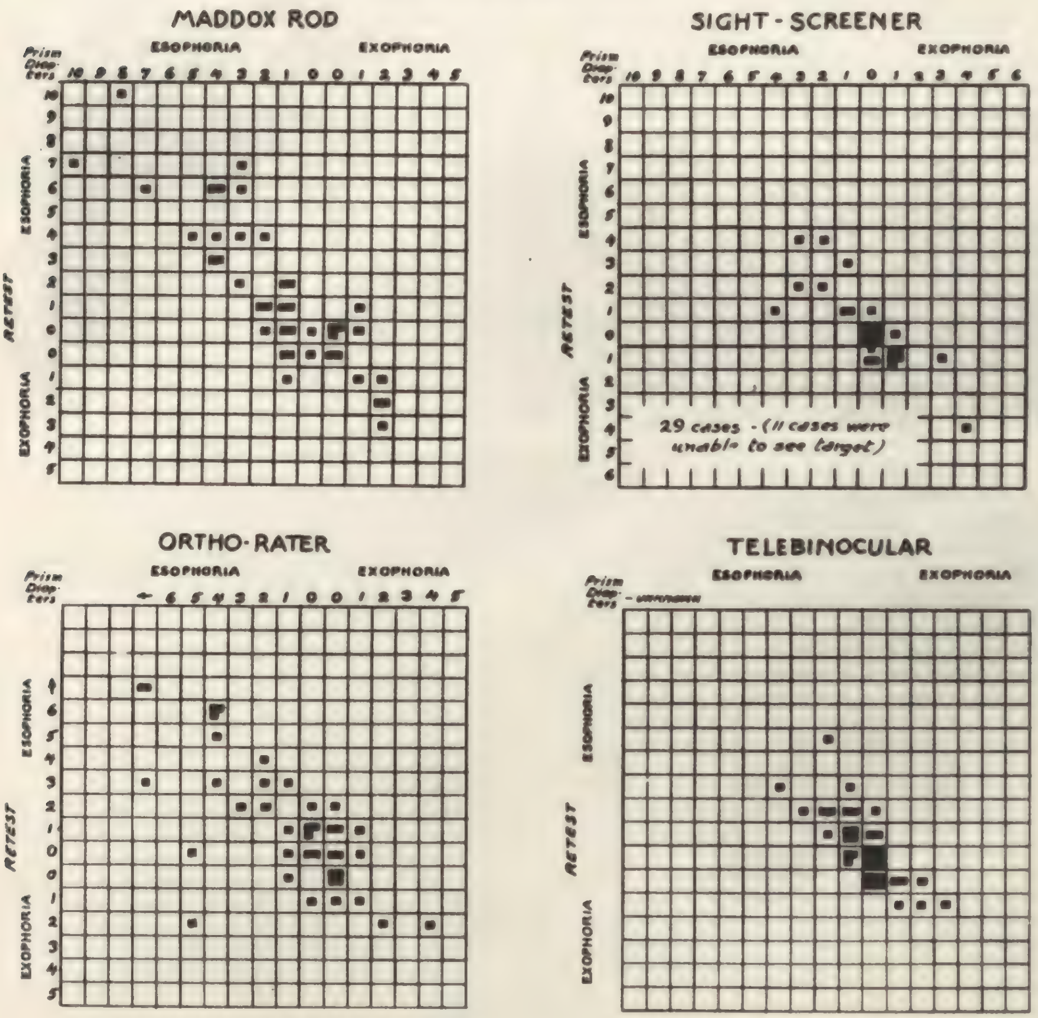
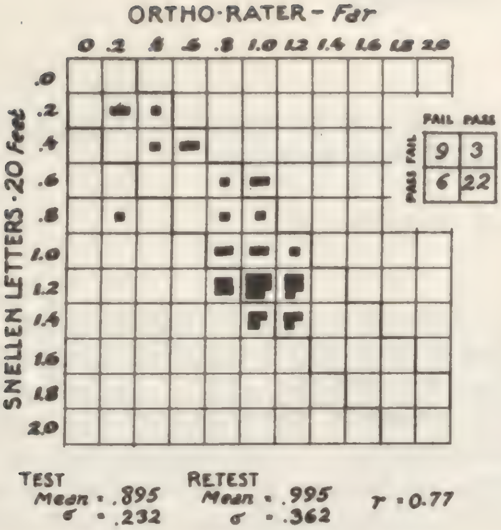
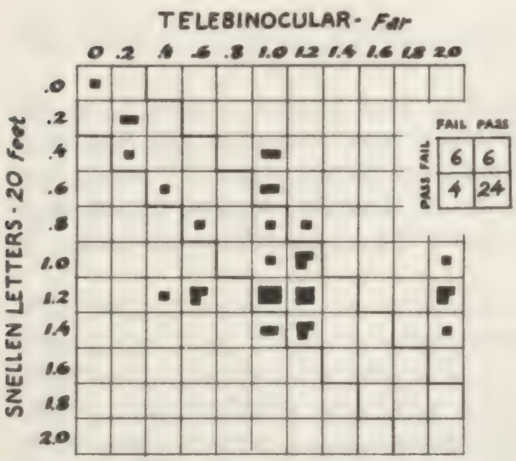


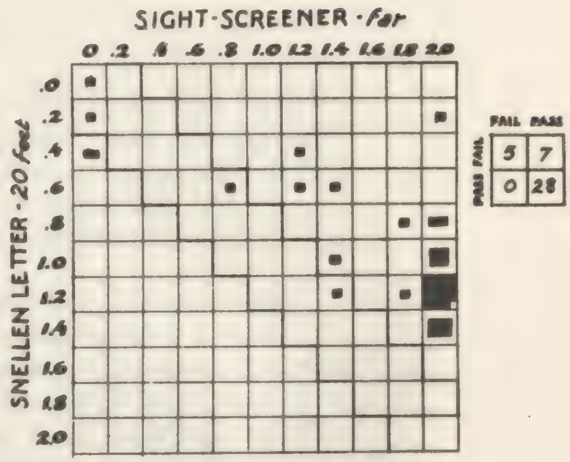
PLATE III

COMPARISON
of Near and Far Acuity Tests with SNELLEN CHARTS

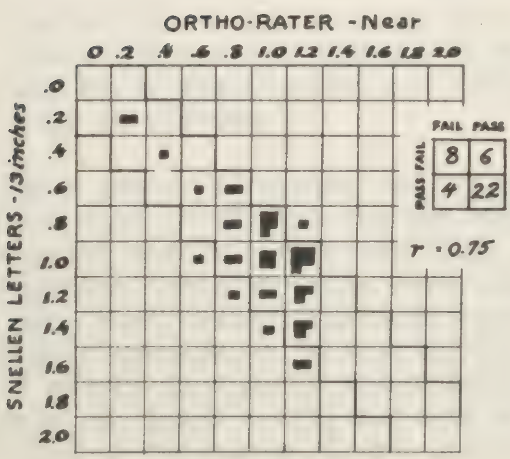


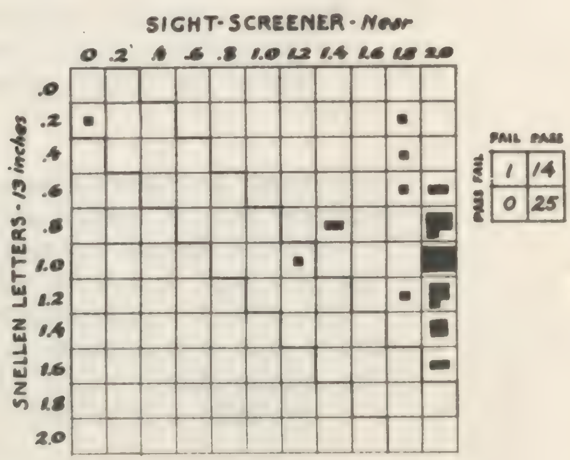
FAR ACUITY





NEAR ACUITY





F. Design of A Study of the Relationships Between Visual Measures and Flight Performance

Dr. Morris S. Viteles

The purpose of this report is to describe the plan of an experiment designed to determine the relationship between visual measures and flight performance. This experiment is being undertaken by the Committee on Selection and Training of Aircraft Pilots at the request of the Civil Aeronautics Administration. The background of this experiment can perhaps be most realistically stated by citing from a letter recently received both by the Civil Aeronautics Administration and the Civil Aeronautics Board.

The writer of this letter states:

"When I was a baby I had infantile glocoma in the right eye and Dr. ------- removed the eye; this was at the age of four. I have grown up with the use of only one eye and don't remember what it is like to see with two so I sense no handicap. My left eye is normal in every way.

"In 1941 I started to work for my private license and built up dual time at considerable expense and I was routinely denied by the C.A.A. Somewhat dismayed I tried other instructors and they all say "You fly well and I'll solo you if the C.A.A. okays it," so I am keeping at it because I know I can fly and fly safely; if the C.A.A doesn't think I should I would like to know exactly why by some conclusive tests while flying the airplane or some device that is used for this purpose.

"After the war is over my wife and I plan to own a plane and enjoy private flying. I work for ------ Airlines and being around airplanes daily surely makes my wings want to stretch."

This letter is typical of the many pleas received from men and women who want to fly but who are denied the right to fly because of some physical defect. Both the Civil Aeronautics Board and the Civil Aeronautics Administration have taken the position that flying should be made more easily available to the individual. A crucial problem in this connection is that of setting standards for the certification of pilots at a point which will permit the certification of all those who can learn to fly and are able to meet the ordinary demands of flying following flight instruction.

Such a point cannot be established with complete satisfaction for any physical measure without experimentation. At least this is the point of view underlying the request for studies of the relationship between physical measures and flight performance which led to the initiation of the present experiment. In passing, it is of interest to note that this request came originally from the Civil Aeronautics Board, which is responsible for formulating the policy and regulations for the certification of pilots. The NRC Committee on Selection and Training of Aircraft Pilots was asked by the Civil Aeronautics Administration to undertake the necessary research for reasons which are best stated by reading from correspondence between the Civil Aeronautics Board and the Civil Aeronautics Administration that led to the development of the present experiment.

> "We have noted with great interest the strides which have been made by your Division and your contractor, the National Research Council, in formulating objective standards for determining the requirements for piloting a plane. We are particularly impressed with the methods which have been developed for improving the objectivity of instructors' and inspectors' judgments of student pilot performance and in providing photographic and other objective devices for measuring pilot performance.
>
> "It occurs to us that the availability of such objective indices of pilot performance places you in an excellent position to explore further, under controlled conditions, the relationship between physical standards and performance in learning to fly during flight. In particular, we are interested in having you do a carefully designed study of the relationships between visual standards and flight performance with respect to the certification of civilian pilots, bearing in mind any justifiable differences in standards between private and commercial pilots.
>
> "You can be assured of our full cooperation in such experimental work if it is acceptable to you and to your contractor."

While the request applied to physical standards in general, the present study is limited to an investigation of the relationship between visual measures and flight performance. In passing, it should be noted that investigations in this area are not new to the Committee on Selection and Training of Aircraft Pilots and to its associates in the Civil Aeronautics Administration. I am certain that many in this group are familiar with the work done independently of the Committee by D. R. Brimhall and R. Franzen, of the Civil Aeronautics Administration, involving an examination of the consistency of visual measures and their significance in relation to accidents. Under the direct auspices of

the Committee on Selection and Training of Aircraft Pilots, there has been a study of the relationship between visual measures and progress in learning to fly on the part of RAF Cadets. The results from this study, while showing the absence of any significant relationship between these two variables, are highly tentative, chiefly because early eliminations were absent from the data accumulated in this study. At the present time a follow-up study on other groups of RAF cadets in this country is under way. However, it is not the purpose of this paper to discuss these earlier studies but rather to outline what the Committee proposes to do in the way of a major, and what is hoped will be a definitive study in this area.

I think it is commonly agreed that such a study is needed as a basis for factually determining the standards to be imposed in order to qualify the largest possible number of applicants for flying certificates without imposing undue hazards upon either the pilot or the general population. The problem is not that of deciding whether such a study should be undertaken, but how it should be designed in order best to accomplish the objectives of the study.

The NRC Committee on Selection and Training of Aircraft Pilots has taken the position that an investigation of the relationship between visual measures and flight performance cannot be properly designed without close cooperation of research personnel representing various areas of interest in the field of vision. The design of the study has therefore been in every sense of the word a cooperative effort, involving the close collaboration of psychologists, ophthalmologists, physiologists, and medical practitioners designated as consultants to the Committee on Selection and Training of Aircraft Pilots by the Aero-Medical Association, the NRC Committee on Medical Problems in Civil Aviation, and the AAF School of Aviation Medicine.

In designing the present investigation, attention has been centered primarily on visual <u>acuity</u>. Stated positively, the hypothesis which the experiment is being designed to test is this:

> Other things being equal, persons with various degrees of visual deficiency will learn to fly and fly as well as persons with nominally "perfect" vision.

One of the first problems encountered in designing the experiment to test this hypothesis involves the selection of visually deficient subjects. In general, two alternatives are available, as follows:

(1) The first calls for the use of subjects giving a continuous distribution of visual efficiency, from no defect to serious defects, throughout the entire range of visual acuity.

(2) The second alternative involves the use of groups of subjects, each with a defined range of visual acuity, representing a level of visual efficiency.

The second alternative seemed best suited for this investigation, since the requirements for the groups can be so formulated as to provide different degrees of visual defect for comparison in terms of flight performance while, at the same time, relative economy in the number of subjects required can be achieved. In addition, an attempt to select subjects covering a continuous range of visual acuity is complicated by the fact that even though a continuum in terms of acuity might be set up, there would still be no assurance that a continuum existed in terms of defects associated with loss of acuity, that is, a continuum in terms of "types of eyes." The use of a continuum is subject to the additional disadvantage of rendering difficult the placement of subjects who exhibit differences between eyes in terms of visual efficiency.

Because of these considerations, it has been decided to use groups of subjects, representing levels of visual efficiency suitable for revealing such differences in flight performance as may be associated with visual deficiency. These include a control group with "normal" uncorrected vision and three experimental groups with varying degrees of visual defect, as follows:

Group A: Unaided vision of 20/20 or better in each eye with high acuity of stereopsis and a refractive error under cycloplegia of less than 0.50 D of myopia in any meridian, 1.50 D of hyperopia in any meridian, and 1.0 D of astigmatism.

Group B: Unaided vision of 20/50 or worse in each eye, corrected with forward glasses to 20/20 or better in each eye, with a high acuity of stereopsis (corrected) and a refractive error under cycloplegia of less than 3.00 D in any meridian, less than 2.00 D of astigmatism and less than 2.00 D of difference between any parallel meridians in the two eyes.

Group C: Unaided vision of 20/100 or worse in each eye, corrected with forward glasses to 20/50 or better in each eye, with (in the judgment of the examiner) a corresponding acuity of stereopsis and a refractive error under cycloplegia exceeding 4.00 D in any meridian.

Group D: One eye having vision of 20/20 or better corrected, with refractive error under cyloplegia of less than 3.00 D in any meridian and less than 2.00 D of astigmatism; the other eye having vision of 20/100 or worse unaided, not correctible to 20/50 with a refractive error under cycloplegia exceeding 4.00 D in every meridian or having been removed at least 5 years prior to application for flight training.

In considering the grouping, it should be noted that Groups C and D include individuals who do not meet the current requirements of CAA for final certification as a private pilot without flight tests to supplement the medical examination. These are what might be called basic experimental groups, with Group A as a basic control group of individuals with normal, uncorrected vision. Group B is of special interest in terms of individuals with defects correctible to a high level of efficiency although this group does not fit so clearly into the present CAA pattern of visual requirements for certification of private pilots.

Having defined the requirements for the experimental and control groups, at least tentatively, it is of considerable importance to determine the proportion of individuals in the population as a whole who fall into these various visual categories. An estimate of the proportion in each group, and of the proportion of the population falling in the gaps between groups, was made by the members of the Committee on Visual Study, under the chairmanship of Dr. W. R. Miles, which has served as a steering committee in working out the statistical design of the experiment. Subsequently, a "revised estimate" was made by Dr. Peter C. Kronfeld, who is acting as a Consultant to the Committee on Selection and Training of Aircraft Pilots, as representative from the Committee on Medical Problems in Civil Aviation. The original and revised estimates are as follows:

	Original Estimate	Revised Estimate
Group A	36.5%	50 %
Between A and B	25 %	24.5%
Group B	25 %	13 %
Between B and C	6 %	3 %
Group C	2.5%	3 %
Between C and D	0.5	2 %
Group D	4.5%	4.5%

According to Dr. Kronfeld, the revised estimates for Groups B, C and D are the most reliable. I am presenting both estimates since members of this group can possibly supply data which will give us a more exact picture of the situation than either of these estimates.

Before proceeding with the discussion of the visual measures to be employed, it seems desirable to re-state the hypothesis which the investigation is designed to test, in terms of the experimental groups which are to be employed. In these terms, and again stated positively, the hypothesis is this:

> Other things being equal, people of the kind represented in Group B (or Group C or Group D) will learn to fly and fly as well as those of the kind represented in Group A.

Time does not permit a full discussion of all of the visual measures to be used in the study. Those to be used were chosen with the view both of (a) furnishing data on the primary and secondary visual requirements for the selection of the four groups and (b) laying the basis of a battery suitable in terms of objectivity, consistency and validity, for field use. Following is a list of the tests with brief comments on each:

Central Acuity will be tested with two different optotypes -- an adaptation of the Bausch and Lomb Ortho-Rater checkerboard pattern and the double broken ring projected by a device such as the Clason Projector. The acuity tests are to be made twice, on successive days, with the two different optotypes.

Phorias and Vergences are to be tested by using the Maddox-Rod Cover Test at 6 meters and at 33 centimeters.

Three tests will be used in the measurement of stereopsis:

a. The Verhoeff Stereopter. A preliminary study may be made in establishing conditions of testing most satisfactory for a measure of adequate reliability.

b. The Ohio State Rectangle-Circle Stereopsis Test, developed by Dr. G. Fry of Ohio State University.

c. The Howard-Dolman Test. This test was included both because of its wide acceptance and in order to obtain data for comparison with those gathered by the Services.

Test for Paralytic Motor Disturbances will be made by the procedure in which the subject fixates successively a target in the center of a screen and targets in the six cardinal positions of gaze, the examiner observing and neutralizing, with a rotary prism, the recovery movements which occur upon removal of an occluder held first over the right, and then over the left eye.

Peripheral Vision will be tested through use of an improved perimeter developed by Dr. F. N. Low, at the University of North Carolina, in a research project sponsored by the NRC Committee on Selection and Training of Aircraft Pilots.

Color Blindness will be tested first by means of the American Optical Company pseudo-isochromatic plates. Subjects who make more than three mistakes on this test will be examined through the use of the AAF School of Aviation Medicine Color Threshold Lantern. It has been tentatively decided that applicants with scores below 35 on this test will be eliminated.

Night Vision will be examined with either the AAF School of Aviation Medicine Portable Night Vision Tester or with the Aero-Medical Laboratory Radium Plaque Night Vision Tester, or both. This test will be employed to eliminate only cases with extreme deficiencies in night vision.

Range of accommodation will be measured using type representing 20/40 of the Snellen system, to be read at 50 centimeters.

Use of the Frontal Plane Apparatus, involving artificial tilting of the frontal plane is under consideration.

In addition to the visual tests, a number of psychological tests will be administered, primarily for use in matching groups. The tests to be used are as follows:

a. Mashburn Serial Reaction Time Test
b. Two-Hand Coordination Test
C. Test of Mechanical Comprehension
d. Otis Test of Mental Ability
e. Desire-To-Fly Inventory
f. Test of Aviation Information
g. Siographical Inventory
h. Ohio State Entrance Examination

Applicants falling below the fifteenth percentile on the Ohio State Entrance Examination will not be eligible for the experiment. Except for this test, no cut-off points are to be set, the test scores being used solely for the purpose of matching groups with respect to a combined aptitude test score. In addition, the groups, each including 50 men and 20 women, will be matched both for age and education. Only individuals between the ages of 17 and 29, inclusive, graduates of high school, will be used as subjects, although the latter requirements may be modified on the basis of a current analysis of available populations.

1. All examinations are to be made at a Visual Testing Center. Applicants will first be screened as to elgibility for the project, through the use of the Ortho-Rater.

2. Applicants passing the screening tests will be referred to an ophthalmologist. The ophthalmologist will:

a. determine the objective refraction under cycloplegia.
b. determine the results of the post cycloplegic test.
c. determine the prescription for the individual, if any.
d. give an appraisal of any disease.
e. make a diagnosis.

3. Applicants will then be referred back to the Vision Testing Center for administration of the complete battery of visual tests.

4. Applicants will then undergo the battery of psychological tests.

5. All pertinent data will be reviewed by the Visual Study Committee on Admissions who will assign subjects to the various groups.

So much for the strictly visual aspects of the experimental design. Although the visual considerations are perhaps of primary interest to this group, from an experimental point of view the criterion measures by means of which the flight proficiency of the subjects is assessed are equally important. Regardless of the effort expended in establishing categories in terms of rigorous visual requirement, the results of the investigation can only be equivocal if the measures of flight proficiency are crude and lacking in precision.

Two major contributions in this area of flight criteria, growing out of research under the auspices of the Committee on Selection and Training of Aircraft Pilots, include <u>standard flights</u> and <u>objective methods for recording and evaluating flight performance</u>.

Plans for "Standard Flights" were developed in research done at the University of Pennsylvania. A standard flight is essentially a standard work sample in terms of which the performance of all students with a comparable degree of training are evaluated. Each flight contains two types of maneuvers, "critical maneuvers" and "transition maneuvers". Critical maneuvers are those to which special attention is being given for purposes of evaluation. Transition maneuvers are those maneuvers, intervening between the critical maneuvers, whose function is to get the plane in a position to enter the next critical maneuver. Standard flights have been developed for a variety of flight training courses, and for the various "stages" of training within each course.

A sample standard flight for Stage D of the old C.P.T. course is shown in Figure 1. It will be noted that the sequence of maneuvers is so ordered that the maximum economy in time required to make the flight is achieved.

In the Visual Study, "check flights", in the form of standard flights, are to be administered by specially trained flight examiners at the seventh, fifteenth, twenty-fifth, and thirty-fifth hour of the flight training course. If the subject has not achieved satisfactory proficiency at the completion of the 35 hour controlled flight, training will be continued, if necessary, up to 50 hours, and he will be given an additional

S T E E P T U R N S

CONTROL USE	LEFT Entry	LEFT Turn	LEFT Recovery	RIGHT Entry	RIGHT Turn	RIGHT Recovery
Simultaneous........	☐	☐	☐	☐	☐	☐
Successive..........	☐	☐	☐	☐	☐	☐
Slips...............	☐	☐	☐	☐	☐	☐
Skids...............	☐	☐	☐	☐	☐	☐
Neither.............	☐	☐	☐	☐	☐	☐
Rudder Pressure:						
Correct.............	☐	☐	☐	☐	☐	☐
Incorrect...........	☐	☐	☐	☐	☐	☐

PRECISION		LEFT	RIGHT
Bank.........	Constant	☐	☐
	Varies	____ °	____
Speed................		____ MPH	____ MPH
Speed is:	Constant	☐	☐
	Varies	____ MPH	____ MPH
Altitude is:	Constant	☐	☐
	Varies	____ ft.	____ ft.
Recovers:	On heading	☐	☐
	Off heading	____ °	____ °

Sample Page
from
OHIO STATE FLIGHT INVENTORY

check flight by the flight examiner when, in the opinion of his instructor, he is qualified to take the private pilot flight test, or in any event, at the 50 hour point. In addition, a flight test will be administered by a CAA inspector immediately following the check flight at the end of 35 hours of training and following subsequent check flights when these are necessary. The CAA inspector will follow the procedures used in the field, assigning over-all grades to the subject's performance, whereas the flight examiner will also obtain other and more objective criterion measures.

The entire series of criteria to be employed in the Visual Study is as follows:

Flight Inspector: Over-all grade on flight test, grades on maneuvers in flight test, score on taxiing obstacle course.

Flight Examiner: Over-all grade on check flight, grades on maneuvers in check flight, score on taxiing obstacle course, Ohio State Flight Inventory measures.

It will be noted that the flight inspector will assign an over-all grade to the subject's performance on the flight as a whole, and will assign maneuver grades in terms of the subject's performance on individual maneuvers. He will also indicate the performance of the subject on a "Taxiing Obstacle Course" administered at the end of the 35 hour check flight.

The flight examiner will also give "Overall Grades" and "Maneuver Grades". In addition he will record pertinent elements of the subject's performance on the Ohio State Flight Inventory. He will also operate the photographic unit by means of which photographic records of performance on certain maneuvers will be obtained. He will also evaluate the performance of the subject on the "Taxiing Obstacle Course" administered during the 35 hour check flight.

In regard to the photographic records, four maneuvers have been selected for intensive study, namely:

Take-off
Straight and Level Flight
360° steep turns
Landing.

These maneuvers are to be executed a sufficient number of times during each check flight so that a reliable work sample will be obtained. Selection of these maneuvers for intensive study is premised on the fact that Take-offs, Landings, Straight and Level, Climbs, Glides, and Turns are considered the "basic" or fundamental maneuvers in that all other maneuvers are essentially variations or combinations of these fundamental

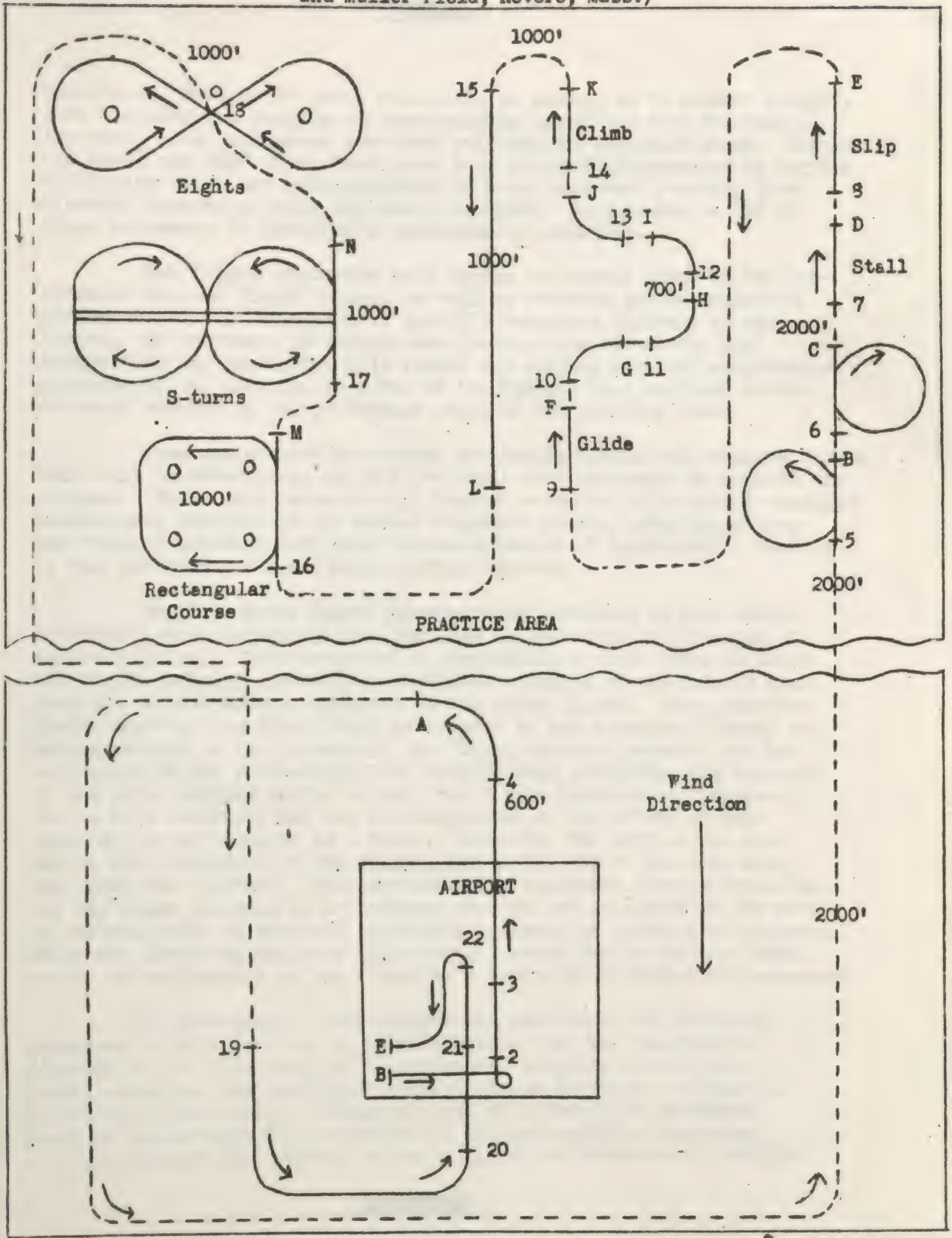
CAMERA FIELD -- PHOTOGRAPHIC INSTALLATION

Rate of Climb | Turn & Bank | Subject No. | Altimeter

Tachometer | Airspeed | Artificial Horizon

STANDARD FLIGHT D

(for use at Boston Metropolitan Airport, Norwood, Mass.
and Muller Field, Revere, Mass.)



November 20, 1941

Prepared by: Morris S. Viteles
Albert S. Thompson
Univ. of Penna.

maneuvers. Because it seems reasonable to assume, on "a priori" grounds, that take-off and landing are particularly associated with the visual function, these maneuvers have been selected for intensive study. Straight and Level and 360° Steep Turns have been selected as maneuvers of varying difficulty which are representative of basic maneuvers possibly less directly associated with the visual function. Performance on all of these maneuvers is amenable to photographic recording.

The flight instructor will assign an overall grade to the performance on each flight lesson, as well as maneuver grades indicating proficiency in the execution of specific maneuvers included in each lesson. In addition, following each landing executed during dual instruction the instructor will record the maximum vertical acceleration produced by the landing, in terms of the reading on a vertical accelerometer mounted in the instrument panel of the training plane.

From administrative records the instructional time required before solo will be determined, as will the total time necessary to complete the courses. These time measures will furnish evidence as to whether visually handicapped individuals can become competent pilots, even though they may require somewhat more than the usual amount of instruction. Certain of the criterion measures merit further comment.

The Ohio State Flight Inventory was developed at Ohio State University as a project of the Committee on Selection and Training of Aircraft Pilots. This inventory is essentially a check sheet on which the flight examiner records the pertinent elements of the pilot's performance on the various maneuvers in the check flight. This criterion device departs from traditional procedures in two respects. First, in making entries on the Inventory, the flight examiner records, not his evaluation of the performance, but exactly what occurred. For instance, if the pilot slipped during a turn, the flight examiner records merely that a slip occurred, and not his evaluation of the effect of this error on the performance as a whole. Secondly, the entries are made not at the completion of the flight, but in the air at the time when the error was observed. This Inventory has undergone several revisions, and the items included in the present version were selected on the basis of several years of research, involving a number of statistical analyses. After the Inventory has been filled out, a score can be obtained indicative of performance on the flight as a whole and on individual maneuvers.

The photographic installation and procedures for analyzing photographic data obtained in this experiment are the outgrowth of research at the University of Pennsylvania, although the original installation has been modified somewhat at our Institute of Aviation Psychology, particularly through the use of a concealed instrument panel in accord with a plan devised at the University of Rochester. Although photographic records do not yield direct measures of certain

areas of pilot performance, such as observance of some of the safety precautions, and exercise of certain types of judgment, the photographic procedure yields records of value in analyzing the skill displayed in the execution of these maneuvers, and those parts of other maneuvers not predominantly dependent upon specific ground reference points. Although not covering such a wide range of performance as the Ohio State Flight Inventory, the photographic procedure has the advantage of being entirely objective and entirely independent of the bias and predispostions of the flight examiner. For the Visual Project two improvements in the photographic unit will be introduced. First, a sweep second clock will be included on the photographic instrument panel. Second, a series of lights will be added to the instrument panel, each light being activated, respectively, by a contact on one of the wheels. Thus, when a given wheel touches the ground, the corresponding light on the instrument panel will flash on.

Extremely accurate measures of performance in landing the plane, probably one of the most critical maneuvers for a study of visually handicapped individuals, will be obtained in terms of the indication of type of landing made (three point; wheel landing, etc.) whether or not there is appreciable bounce, duration of bounce, etc. Definitive scoring procedures in terms of these measures await preliminary research in the field. However, it should be noted that photographic records yield measures both in terms of specific critical elements of performance, as discussed above, and also in terms of measures useful in evaluating flight performance as a whole.

One of the most difficult problems in the Visual Study results from possible bias of the inspector or flight examiner with respect to subjects whom he may suspect of being visually handicapped. The photographic records represent one criterion measure which such possible bias will not affect.

The use of the vertical accelerometer in measuring smoothness of landing was suggested by work done in Britain by W/Cdr. P. A. R. Bremridge, RAF. The vertical accelerometer is to be used to give an index to smoothness of landings during dual instruction and will be mounted in the instrument panel of all training planes. The instrument is set at zero by the instructor just before the landing is made, a "smooth" landing being one in which little vertical acceleration is produced when the plane contacts the ground. Data on a large number of landings will enable an intensive study to be made of the rates of learning of the various experimental groups and of the control group in regard to this maneuver.

The instructor's observations on dual landings will be recorded on a suitable form. The instructor will record the "G", or

vertical acceleration, circle appropriate letter or letters indicating which wheels contacted the ground first, and indicate whether the landing was made with or without bouncing.

Another important area of performance is Taxiing. On crowded airports there is a much greater probability of taxiing into another plane or other obstruction, than of coming in contact with another plane or obstruction while flying. Moreover, judgment of distances while taxiing must, in general, be considerably more precise when the plane is taxiing on the airport, than when it is in the air, and it is with such precision judgments of distance that visual deficiencies might, on "a priori" grounds, be considered to represent a major handicap.

A "Taxiing Obstacle Course" has therefore been set up to test the subject's ability to avoid obstacles while taxiing and generally to handle the plane competently on the ground. This will be administered by the flight examiner, and again by the inspector during the criterion flight at the 35 hour point. Wheel obstructions will be represented by ordinary sandbags, or squares of cloth, which will be sufficiently low not to cause damage to the tail surfaces, or to the fuselage covering in front of the tail wheel. Wing obstructions will be a type of pylon, the top part which might come in contact with the plane being padded, and the entire unit being so constructed that it will be tipped over by contact with a plane, without damage to the aircraft.

The subject will be required to taxi through the course, park the plane between the other planes standing on the "parking line", and taxi back through the course to the point at which he started originally. It will be the flight examiner's responsibility to see that the student does not actually hit the planes between which he is instructed to park. The subject is to avoid all obstacles, and to keep the wheels of the plane within the boundary lines, except when parking the plane. He will be cautioned that while safety is very much more important than speed, the time required to cover the taxi pattern will be given consideration in grading his performance. Evaluation will be in terms of number of obstacles contacted, ability to park the plane on the "parking line", and the elapsed time for the course.

Considering these criterion measures it might be observed that the CAA inspector's grade on the Private Pilot Flight Test is, in a sense, the most "practical" criterion, since this determines whether or not the student qualifies for the private license. However, Committee research has indicated that in many cases the inspector's grade is not always reliable, and frequently disagrees with what instruments show concerning the quality of flight performance. Therefore, the other criterion measures, some of which can be defined operationally in terms of instrument readings, are of great importance in evaluating the flight proficiency of the subjects in the various groups and in providing a

definitive answer to the hypothesis which the investigation is designed to test.

The data from this experiment will be evaluated by analysis of variance, and possibly through use of analysis of covariance. However, consideration of the statistical design presents one more problem which may be of interest to this group. This involves the number of cases necessary in order to reach unequivocal conclusions. If there are large differences in proficiency between groups, a small number of cases will render the differences statistically significant. However, if differences in proficiency are small, a larger sample will be necessary to render such differences significant statistically, although the differences may in themselves have no practical significance.

The solution to this problem would seem to hinge on determining what differences in proficiency are significant from a purely practical point of view, that is, from the point of view of the effect of such differences on the day to day performance of the prospective pilot. Once the differences, in terms of the various criterion measures which are of practical importance have been established, the size of the samples necessary to render these practical differences statistically significant can be estimated. This estimation, of course, depends upon the variance of the scores on the several criterion measures. It is hoped that this estimate can be made through examination of data from previous research projects of the Committee, and by preliminary experimentation. Steps are being taken to obtain such estimates, both of the absolute differences which can be considered practically significant, and of the variance of scores in the population. It is altogether possible that the number of cases in the experimental and control groups, set arbitrarily at 50 men and 20 women, will have to be increased.

The Visual Project is to be initiated at Ohio State University, as a project of a newly established Institute of Aviation Psychology under contract with the National Research Council Committee on Selection and Training of Aircraft Pilots. It is hoped that this experiment will not only furnish definitive results on the relation between visual measures and flight performance, but set the stage for other experiments, calling for similar cooperation among professional groups, in regard to other sensory and physical standards.

Discussion:

Ens. Curtis asked how the problem of instructor variability would be solved. Dr. Viteles explained that it would not be feasible to give the instructors a special training course, but standard instruction methods will be used, and each instructor will teach subjects from each group.

Lt. Orlansky suggested that the educational standards set for the subjects might be too high if the research is to form the basis for the certification of the general public. Dr. Viteles agreed that it would be better to have a sample of the total population, but more cases and more time than is available would be required. It had been decided to eliminate variables of intelligence and similar factors in order to concentrate on visual differences.

Ens. Curtis pointed out that some flight maneuvers have little relation to vision and asked if any attempt had been made to determine which ones are related to visual skills. Dr. Viteles answered that the flight maneuvers have been broken down in great detail.

Lt. Comdr. Peckham suggested that the results on the Ortho-Rater be corrected for individual differences in interpupillary distance. Dr. Viteles explained that the Ortho-Rater results are to be used in screening subjects for Groups C and D. The findings will be used in no other way.

Comdr. Wolpaw commented that the ability to land in unfamiliar and relatively undifferentiated terrain should be recorded in a study of flying ability. Dr. Viteles said that two methods for dealing with this problem had been considered: (1) to have the subject record what he sees on a portable wire recorder, and (2) to have the subject check a list of selected objects for those he has sighted.

H. Four Variables in Testing Visual Acuity

Lt. Dean Farnsworth

I am not bringing anything new to your attention today. We have nothing to report that has not been known for 20, 40, or 60 years. But in spite of all the information so long avaiable, the Navy standards and methods of administering visual tests have not been changed. The visual examination is one of the largest factors responsible for disqualifications. Not only do the methods of administration vary from station to station, but they also vary from day to day within the same station, and for reasons which could be remedied easily. I do not propose to discuss qualification standards for those can be made meaningful only after the tests have been made reliable.

There is much that we do not know about vision, but on four big questions we do have enough material with which to proceed with immediate standardization.

I

The first of those four variables is the physical condition of the men being examined. It is recognized generally that, among the organs of the body, the eyes are among the most responsive to physical debility. Let me illustrate with a recent clinical, and uncontrolled, but convincing experiment. When we started the Ortho-Rater screening tests on vision, we found that the same standards were disqualifying many more New Construction men than "boots". Yet various reports in the last war and the present one would not lead to the expectation that general Service conditions should produce permanent impairment of vision. Investigation showed that certain New Construction men had surreptitious methods of getting off the Base which the "boots" did not. On a certain Thursday afternoon we called the Chief of the barracks and arranged to prevent all liberties the night before testing. Disqualifications dropped immediately. In preparation for this meeting I asked Miss Kindred, in charge of Radar Selection, to total the scores of the New Construction men for the 2 weeks before and the 2 weeks after this Thursday interview with the Chief. The results are shown in Figure 1. Note that the mere expedient of keeping all men aboard resulted in but a little over half the disqualifications for vision which occurred when some of the men were allowed liberty and beer the night before. This is not presented as a new fact, but as a factor which is daily influencing our qualifying and disqualifying scores.

II

As long as there have been doctors or pharmacist's mates in the Navy it has been known that examination scores vary with the man who gives the test. Yet apparently no rules have been made to insure uniformity of training or techniques. It is not to be expected that a raw pharmacist's mate, thirdclass, would give a man the same acuity rating as an ophthalmologist; or that an experienced and conscientious pharmacist's mate would give a man the same acuity score as some seaman who is pulled off the swabbing detail and told to screen 180 boots by noon. Furthermore, untrained and inexperienced administrators can be fooled by every one of the tricks known to practically all seamen who have been in the service a month: peeking through the fingers, squinting with the eyelids, tilting the head to compensate for astigmatism, pressing the occluder against the eyeball, peering around the occluder, etc. It is difficult to run a check experiment on this question, but it is scarcely plausible that a man leaves Pearl Harbor, Norfolk, or Great Lakes with 20/20 vision and cannot make 15/20 in New London, Conn. Such widely variant scores between stations, and the fact that there are men with 10/20 and 14/20 vision from the old Navy who repeatedly pass their physical examinations, are sufficient evidence that irregular administration may possibly be the biggest loophole in visual examinations.

III

It is axiomatic that acuity or retinal resolution is a function of brightness contrast of the test object, or, more briefly, of illumination of the test object. However, check tests made with a foot-candle meter at half a dozen stations have revealed illuminations varying from 8 foot-candles to 300 foot-candles on the test chart. In some of the transilluminated viewing test boxes, the brightness may run even higher. In some places men are tested with full adaptation to the light surround; in others the testee is expected to step from a lighted room into a black alley and immediately read a series of test objects of high contrast. As a check test on this, and within very reasonable limits, two illuminations were used on the same group of men in our 20 foot testing range. A Snellen chart was presented under 12 foot-candle illumination and then under 73 foot-candles (a difference of less than one log unit), with the results shown in Figure 2. It is seen that the modal acuity score of this group is supposed to have changed from 1.2 to 1.6 in one hour. Nearly three times as many seamen read the 20/20 line at the higher level of illumination.

In view of these three variables which obtain throughout the United States Navy, and probably other services as well, what

reliability can result from any criterion specified in the present regulations for acuity?

IV

However, over and above all this is the most uncertain and unstandardized part of the whole picture: that of the type of test object employed. The traditional test in the Navy has been something called the Snellen charts. The ones in use throughout the Navy surely were not made by Mr. Snellen; they are made by commercial firms whose draftsmen know nothing of the science of optics, and they are printed from plates which are usually run until the letter edges smash down into a blur. Ferree and Rand (1937) measured differences among test letters on commercial charts which amounted to 25%. A variety of test objects have been devised; theoretically the Ortho-Rater checkerboard is probably the ideal test object. Others are illustrated in Figure 3. The Snellen test letters may not be the best test item in the world; but for the time being they are usable and convenient devices and would function very well indeed if equated in difficulty. The need for an equated chart is so apparent that several activities, working independently, have lately begun the work. The original letters with which we started, as ~~Coates (1935)~~, Sheard (1918), Jackson (A.M.A. Report, 1916), and others have reported, differ in difficulty by as much as 50%. The Submarine Base chart letters have, as shown in Figure 4, been reduced to an all-over difference in difficulty of approximately .1 decimal unit. One more revision would probably cut these differences in half, which would be a vast improvement over our present charts and probably constitute a degree of variability less than that of the three previously mentioned variables.

The lack of standardization of these four variables continues to cause extravagant waste of men, money, time, and materials. In view of the fact that the knowledge necessary to standardize these four variables within reasonable limits is available, this is an opportune time for the Army-Navy-OSRD Vision Committee to take action upon such standardization.

First, it is reasonable to propose that the Service manuals be revised to require that, for a period of not less than the 48 hours prior to testing, the activities of the subjects be controlled to prevent dissipation or extraordinary physical exertion. Consideration might be given to provision for increased reliability by a requirement for retesting.

Second, it is reasonable that a certain training and experience be prescribed for pharmacist's mates, or others, who will administer the tests.

Third, some reasonable illumination level should be adopted for the test charts and a surround specified which is not markedly contrasting with that of the chart brightness (LeGrand Hardy, 1934). In this day when even amateur photographers have foot-candle meters, the brightness can be defined in foot-candles with practicability. The lower limit is not less than 10 foot candles, which approximates the critical level of differentiation, and the upper limit is in the region of 25 or 30 foot-candles, since this is obtained readily by modern lighting installation. The walls should be painted with a neutral paint of not less than 30% reflectance.

Fourth, until test objects of minimum separable resolution have been tried out throughly in the field, it is reasonable to suggest that properly printed Snellen charts whose letters are equated in difficulty should be issued to all stations with instructions to destroy the present issues.

It might reasonably be made the job of this committee to work out standards of administration for visual acuity which could be adopted by all the Services.

Fig. 1

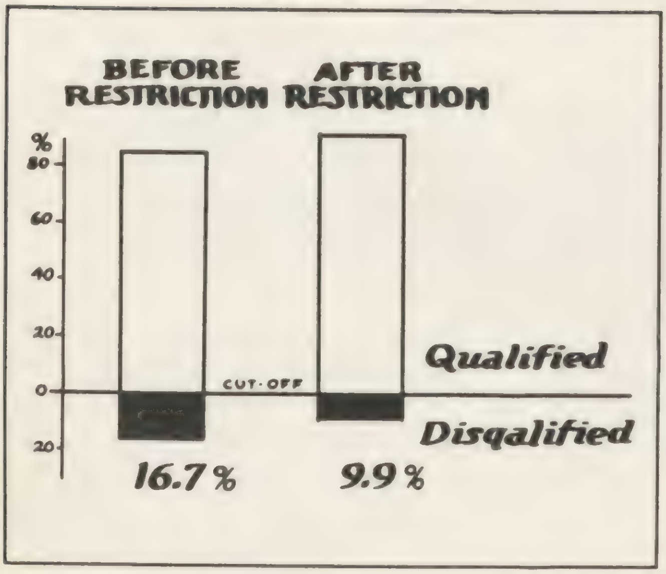


Fig. 3

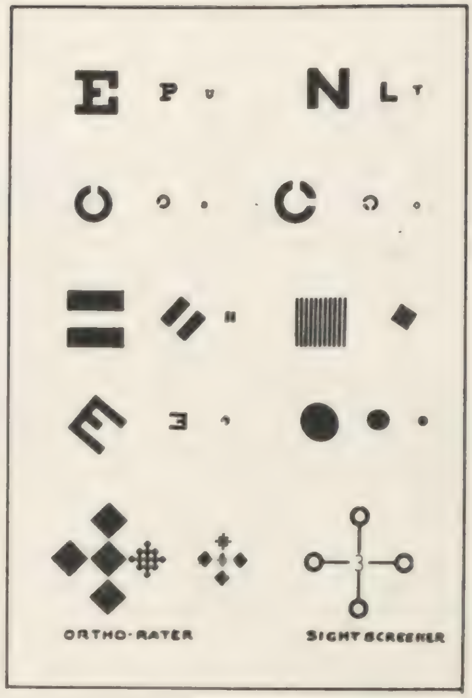


Fig. 2

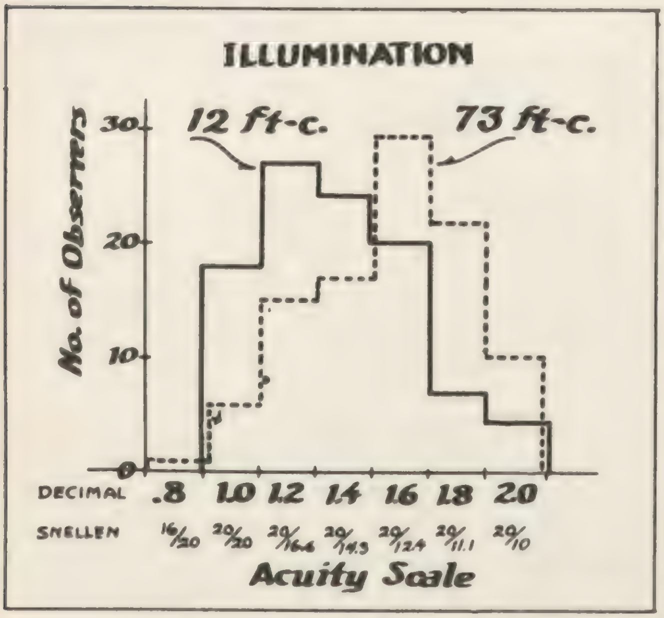
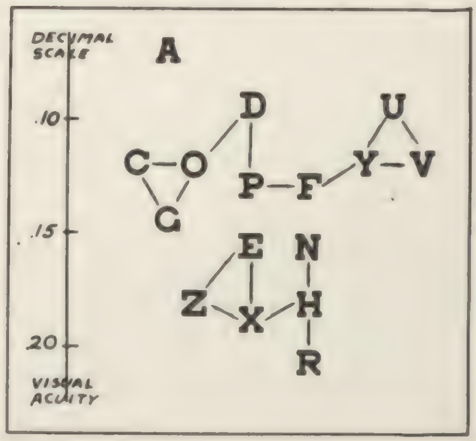


Fig. 4



I. New Design of Acuity Test Object

Lt. Comdr. R. H. Peckham

At a meeting of Naval officers involved in research on visual screening devices, in February, it was recommended that improved clinical tests be developed for measuring visual acuity. Such a recommendation is not unusual among men who use our present standard Snellen and Grow Tests for visual acuity testing.

It was therefore decided to try to prepare test targets whose purpose would be directed towards measuring resolving power, rather than ability to read letters. One such target, which was partly devised by the author in 1936, is found in the Ortho-Rater, a visual screening device made by the Bausch and Lomb Optical Company. The target consists of a checkerboard, black and white, arranged in a symmetrical four-sided figure which decreases in size for visual acuity measurement. The subject reports the smallest target in which he can see the checker squares. When the target becomes too small, all parts look alike. This test has a reliability at least better than the Snellen chart.

The American Optical Company prepared a target which did not decrease in apparent size, but which contained a decreasing element for the measurement of visual acuity. This target consisted of a broken ring of standard size for all values, but with the broken segment increasingly small. Measurement with this target has been reported today by Lt. Sulzman (MC) USNR, who found that the target was unsuccessful, since all subjects could see the target at all sizes. At the suggestion of the author, a new target is being prepared by the American Optical Company, which will maintain the principle of unchanging over-all size, but which will permit estimate of visual acuity by a system of increasingly small triangles. This target will be presented at the next meeting of this Committee.

The choice of units for decreasing size of test targets has been variable. A standard proposed for present research will be provided in the new clinical resolving power targets being prepared. The table below shows the units involved, where "a" represents the visual angle of the target elements.

From this table it is seen that the difference between sucessive tests is a constant logarithmic unit. To the base 10 this amounts to 0.075, to the base 2, it amounts to 0.25. The reason for a choice of constant logarithmic decrement has been to make the tests near the limen equally hard to a person of good or of poor

Minutes of visual angle (a)	Snellen type score (Navy)	Reciprocal score (10/a)	$Log_{10} 10/a$	$Log_2 8/a$
8.0	2.5/20	1.3	.097	0.0
6.73	3/20	1.5	.172	0.25
5.65	3.75/20	1.8	.248	0.50
4.75	4.2/20	2.1	.322	0.75
4.00	5/20	2.5	.398	1.00
3.39	5.9/20	2.9	.466	1.25
2.82	7.5/20	3.6	.550	1.50
2.38	8.4/20	4.2	.623	1.75
2.00	10/20	5.0	.699	2.00
1.69	11.9/20	5.4	.773	2.25
1.41	14.2/20	7.1	.851	2.50
1.19	16.8/20	8.5	.924	2.75
1.00	20/20	10	1.000	3.00
0.84	20/16.9	12	1.074	3.25
0.71	20/14.2	14	1.149	3.50
0.59	20/12	17	1.226	3.75
0.50	20/10	20	1.301	4.00

visual acuity. Each single test size bears a constant ratio to its predecessor. The choice of logarithms to the base 2 permits setting the scale exactly to certain current Snellen type fractions, viz. 10/20, 20/20, and 20/10.

An attempt to force an arbitrary scale on visual acuity measurements, by increasing the r elative number of steps near the average limen, has been made on the present target in the Ortho-Rater. The relative difference between the targets near the equivalent of 20/20 (1 min. of angle) has been reduced, in order to create an artifactually "normal" distribution curve, for allegedly statistical purposes. The change of scale has not affected the real visual acuity of the population, however, but has only resulted in the substitution of an ordinal scale for a cardinal one. This substitution precludes any cardinal treatment of data taken on this instrument, thus excluding computation of Pearsonian correlations, and defeating the very purpose for which it was designed. Furthermore, the fact that visual acuity is limited in emmetropic persons to resolving power, which is an anatomical limit, while visual acuity is limited in ammetropic persons by the dgree of blurring of the image, should not be hidden by such artificial shifting of ordinate values.

The two major optical companies, Bausch and Lomb, and the American Optical Company, are closely cooperating with the Navy in the preparation of visual acuity tests for clinical use, at both distances of 20 feet and 13 inches. Further samples of their developments should be available for presentation at the next meeting of this Committee.

Demonstration of Screening Devices

A Bausch and Lomb Ortho-Rater, and an American Optical Co. Sight Screener, were exhibited to the Committee.

The Ortho-Rater measures:

1. Visual acuity, both eyes, at distance
2. Visual acuity, right eye, at distance
3. Visual acuity, left eye, at distance
4. Vertical phoria, at distance
5. Horizontal phoria, at distance
6. Stereopsis, at distance
7. Color vision, at distance
8. Visual acuity, both eyes, at near
9. Visual acuity, right eye, at near
10. Visual acuity, left eye, at near
11. Vertical phoria, at near
12. Horizontal phoria, at near

The Sight Screener measures:

1. Suspension or monocular supression of vision and prism divergence.
2. Stereopsis, at distance
3. Vertical phoria, at distance
4. Horizontal phoria, at distance
5. Visual acuity, both eyes, at distance
6. Visual acuity, left eye, at distance
7. Visual acuity, right eye, at distance
8. Visual acuity, both eyes, at near
9. Visual acuity, right eye, at near
10. Visual acuity, left eye, at near
11. Vertical phoria at near
12. Horizontal phoria, at near

The optical systems of these instruments are different. The Ortho-Rater is in effect a Brewster stereoscope. Both distance and near tests are provided by means of virtual images. Interpupillary distances

influence the convergence. The centers of the phoria targets are arbitrary to offset "instrument convergence". Two target positions are provided. The lenses must be changed by the operator from the "distance" position to the "near" position. The Sight Screener is a polarizing stereoscope. There are no lenses used for the "near" position. A virtual image is provided for the "distance" position. Interpupillary distances do not influence the convergence. The centers of the phoria targets are optically correct. Changes in target position and interposition of lenses for distance position is automatic.

Objections and compliments have been expressed concerning the test targets in both instruments. The Ortho-Rater visual acuity target has a useful pattern, although units are distorted from a cardinal scale. Personnel could easily memorize the correct answer. The vertical phoria test seems reliable, but can be memorized. The horizontal phoria test contains "fusion" elements, believed to be a bad feature, and can be memorized. The stereopsis test is of such great disparity in the grosser portions that the three dimensional illusion is destroyed in many cases. The color test is photographic, and is not considered to be sufficient.

The Sight Screener supression test is adequate, but the prism divergence amount has been questioned. The stereopsis test is satisfactory. The vertical phoria test may be awkward to administer. The horizontal phoria test uses letters in random order instead of numbers and might be very difficult to memorize. The visual acuity test with broken rings was unsuccessful. (An adequate Snellen letter test was originally provided).

Both instruments, as any other standard test, could possibly be passed by personnel who memorized the test targets, and variable or alternate targets may need to be provided for military selection purposes.

~~CONFIDENTIAL~~

11, pt. 2

SUPPLEMENT [or pt 2]
to

M I N U T E S A N D P R O C E E D I N G S

of the eleventh meeting of the

ARMY - NAVY - OSRD VISION COMMITTEE

10 April 1945

National Academy of Sciences
Washington, D. C.

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U.S. Armed Forces-NRC Vision
111 Committee

8. FURTHER INVESTIGATION ON TRACER FIRE FILTERS

Lt. Comdr. R. H. Peckham

A report by Bunker and Solandt of the Royal Canadian Navy (Proceedings, eighth meeting, pp. 20-25) suggests a certain colored lens to facilitate the observation of tracer bullets in the vicinity of the sun. This report includes a spectrograph of tracer material burned in a forced draft and the spectrographs of two assembled tracer filters. The report concludes that a certain dichromatic combination with its principal transmission in the blue is the best filter for observation of tracer fire near the sun. However, observation of this filter under other conditions indicates that the filter is too dark for ordinary use.

At the request of the Bureau of Medicine and Surgery, the Naval Research Laboratory has prepared exhaustive flame spectrographs of three typical tracer powders: M_2, R226, and 394440. The observation was made by Bunker and Solandt that tracer powders burned with a different apparent color when in a stream of air. It is difficult to comprehend why this would be so since the colors of tracer flames are due to their metallic constituents. Furthermore, the tracer powder is burned partly at least within the hollow end of the projectile. The flames studied at the Naval Research Laboratory were made by burning tracer powder under a chimney.

An example of the flame spectrum of a tracer powder (M_2) is shown in Figure I. Similar detailed tracings are available for the other powders if requested. The difficulty of the mathematical handling of such an irregular curve leads to the preparation of the smoothed curve shown also in Figure I. This smooth curve was visually estimated to approach the same relative energy values for the spectral range involved. That this was accomplished is shown in Table I. Section A of Table I indicates part of the computation of the X - value (red component) of the tri-stimulus curves. These values have been taken from Table XII (weighted ordinates for equal energy) of Hardy's Handbook of Colorimetry, and are computed from the fourth decimal place. Computations were made for each two millimicrons reading to three significant figures from the curve. The relative value of the summated x's showed 22.29% of the total of $\bar{x}$. In Section B, Table I, the computations of the smoothed curve for each 10 millimicrons with $\bar{x}$ estimated to three decimal places shows a relative value of the summated x's of 22.49%. Thus, the smoothed curve is in error by less than 1%. Computations from these smoothed curves require about 1/12th the arithmetical effort.

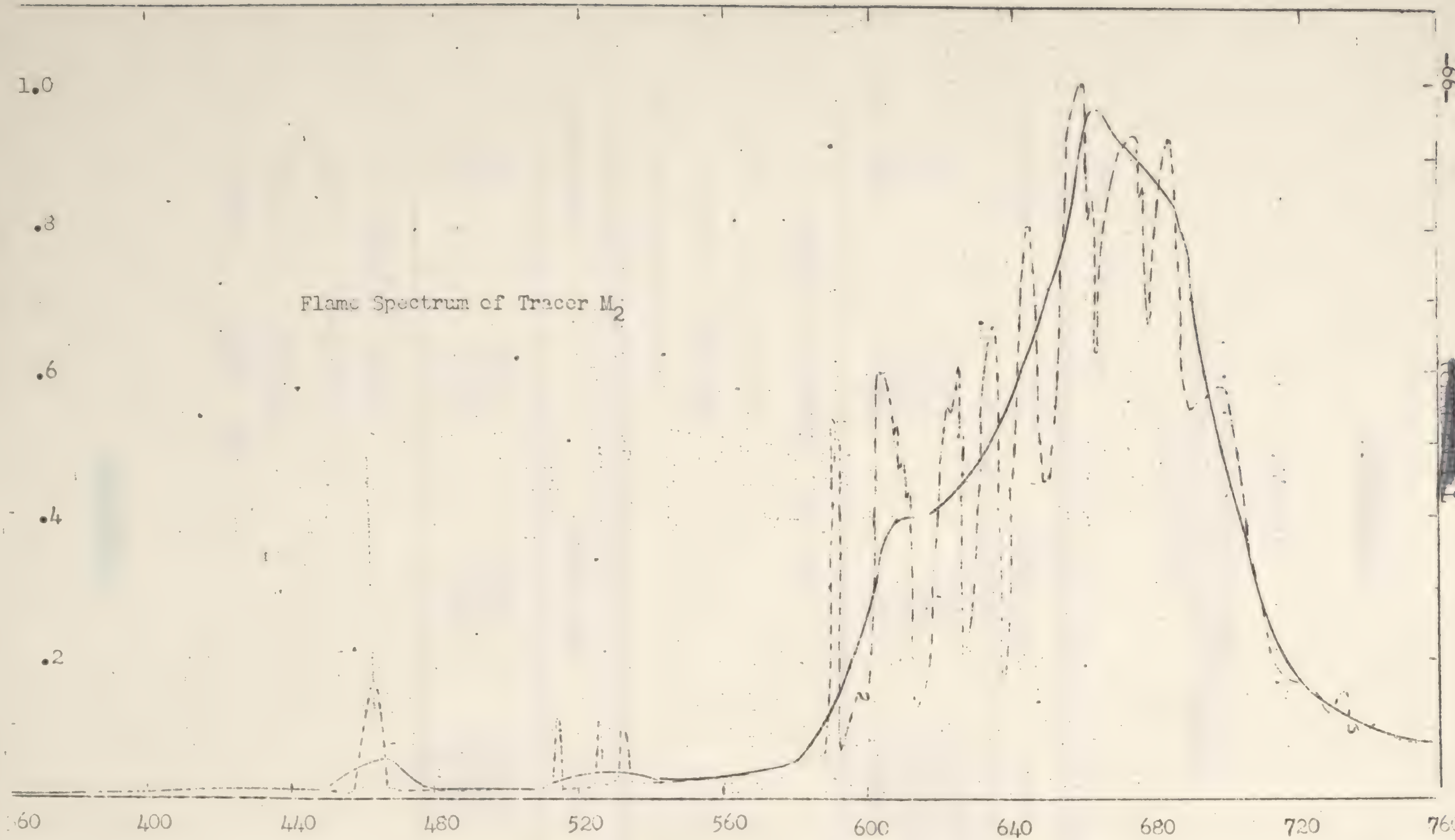

Figure 1 - Tracer Fire, Red M_2

TABLE I

COMPARATIVE COMPUTATIONS:
Examples from Table XII, Hardy's <u>Handbook of Colorimetry</u>

A. From original curve:

Wavelength	$\bar{x}$	Energy value	Product
620	0.8545	0.400	0.3418000
622	0.8154	0.543	0.4427622
624	0.7732	0.600	0.906[illegible]822
626	0.7295	0.570	0.4158150

Σ products = 11.8978906 (380 - 780)

$\Sigma\ \bar{x}$ = 53.3623

Value of x = $22.29_6\%$

B. From smoothed curve:

Wavelength	$\bar{x}$	Energy value	Product
610	1.003	0.39	0.39117
620	0.854	0.40	0.34160
630	0.642	0.46	0.29532

Σ products = 2.402

$\Sigma\ \bar{x}$ = 10.678

Value of x = $22.49_4\%$

Error $= \frac{.2}{22.3} < 1\%$

[redacted]

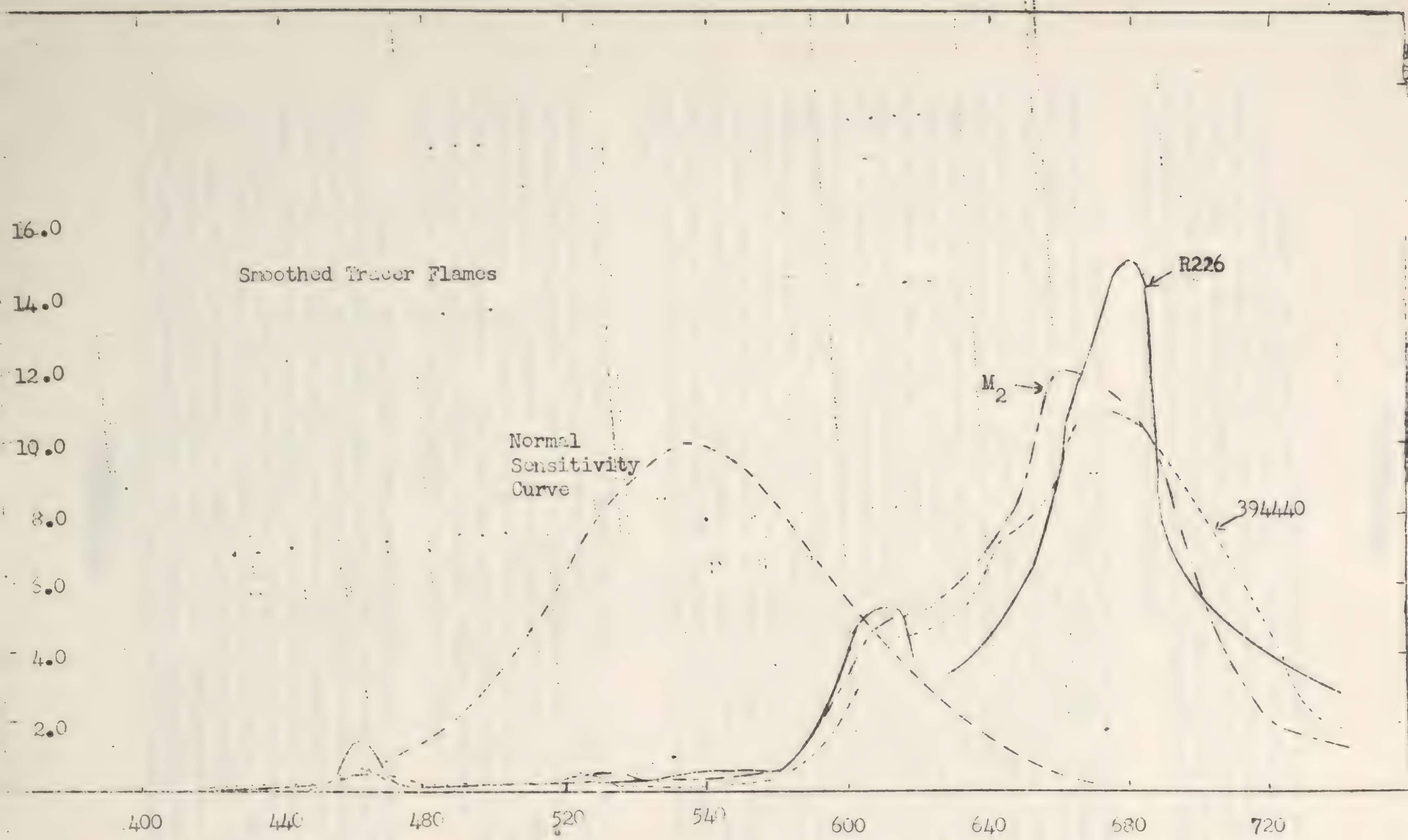

Figure 2 - Tracer Flames

Bunker and Solandt emphasized the importance of the peak at approximately 460 millimicrons (blue), stating that the effect of burning in a stream of air is apparently to increase the effectiveness of this peak, since tracer powders appear brighter in air than in a quietly burning flame. It is possible that this shift of color is an adaptation phenomenon due to differences in energy levels between the burning tracer powder and the background.

The computation of the tri-stimulus values of the tracer material M_2 indicates $x = .620$, $y = .332$, and $z = .048$. Although more accurate computation is possible, it is not considered essential unless a very critical choice is to be made between specific powders, or specific filters, nearly alike. Computation of the appearance of this burning powder through the red tracer filter (XR18M-Polaroid) which is being used extensively, shows that the effect of this filter from the point of view of the "standard observer" is to place the burning powder at the point $x = .695$, $y = .304$. In terms of Hardy's color specification, this represents dominant wavelength of 626 and purity of nearly 100%. The transmission of the red filter to the colored light from the burning powder can be estimated from this computation to be 57.2%. The transmission of the red filter with reference to Illuminant "C" is 14%. Hence the result of viewing tracer fire through this red filter is to reduce color contrast to a minimum, and to raise the brightness contrast towards a maximum. Similar computations can be performed for other filters. The results for this single filter combination are discussed in detail above more as a guide than to demonstrate the value of this particular filter.

Figure II shows similar smoothed curves for the three tracer powders studied. The values of these curves will be found in Table II for each 10 millimicrons from 400 to 740 millimicrons. These values are presented as of interest to investigators who may try to produce a tracer filter. The curves have been reduced to equal energy totals for each of the powders. The absolute units of this energy cannot be stated since two major variables are always present, background brightness and the area of burning powder for various calibers.

Several filters have been proposed for detection of tracer fire. One which has been popular in both Army and Navy is the red filter which cuts off fairly sharply at 570 millimicrons, discussed above. The Army has reported a preference for a peculiar green filter known as MG30, which is polarizing, and which has moderate dichromatic properties. The Canadian choice for a purple filter has been described. Each of these three different filters can be considered as a rational and highly efficient approach to the solution of the problem. Figure III indicates a grossly smoothed curve for the flame spectrum of tracer fire. On the same figure are indicated the spectral curves of the three tracer filters mentioned above and a fourth theoretical filter.

TABLE II

VALUES FOR CURVES IN FIGURE II

	M_2	R226	394440	Ill. "C"
400	0.1	0.1	0.1	0
410	0.1	0.1	0.1	0
420	0.1	0.1	0.1	0
430	0.1	0.1	0.1	0.1
440	0.1	0.1	0.1	0.3
450	0.1	0.1	0.1	0.4
460	0.6	1.5	0.7	0.7
470	0.4	0.2	0.1	1.1
480	0.1	0.2	0.1	1.6
490	0.1	0.2	0.1	2.4
500	0.1	0.2	0.1	3.4
510	0.1	0.3	0.3	4.8
520	0.4	0.3	0.5	6.5
530	0.5	0.3	0.2	7.9
540	0.4	0.3	0.1	9.1
550	0.3	0.5	0.2	9.8
560	0.4	0.5	0.2	9.8
570	0.5	0.5	0.3	9.1
580	0.6	0.6	0.6	8.0
590	1.9	1.8	1.2	6.6
600	3.4	4.5	2.7	5.4
610	4.9	5.3	4.4	4.2
620	5.1	3.2	4.6	3.2
630	5.9	3.5	5.1	2.2
640	7.1	4.5	6.8	1.4
650	8.9	6.2	7.8	0.9
660	12.0	9.0	9.1	0.5
670	11.6	12.7	10.9	0.3
680	10.8	15.1	10.6	0.2
690	9.0	7.5	9.5	0.1
700	5.8	5.7	8.0	0.0
710	3.6	4.7	6.5	0.0
720	2.0	3.9	4.5	0.0
730	1.6	3.3	2.4	0.0
740	1.3	2.9	1.8	0.0
Total	100.0	100.0	100.0	100.0

The purpose of tracer filters is to provide maximum visibility of tracer fire. This visibility can be accomplished by creating a maximum brightness contrast, a maximum color contrast, or a compromise towards maximum visibility between these two extremes. The red filter approaches the condition of maximum brightness contrast. This results in a red visual field containing a brilliant red point of fire. The disadvantage of this solution lies in the loss of color perception caused by the use of a deep red filter. The Canadian filter directs its solution towards the establishment of maximum color difference. The background is rendered blue and the tracer is maintained red. The visual transmission of this filter is extremely low and hence its use is limited to the area near the sun, or the actual solar disc. Since both blue and red light are present in the field, the use of this filter results in chromatic abberation in the retinal image. This abberation can be annoying. The use of the green polarizing filter approaches the problem in the direction of a solution for maximum visibility. The dichromatism of this green filter creates a fairly good color contrast. The relative reduction of the total visual light of the field with respect to the smaller reduction of the tracer fire creates a relatively high brightness contrast. The addition of a polarizing element increases this brightness contrast in direct proportion to the amount of polarization of the field illumination. Under some conditions, therefore, the brightness contrast will be greatly enhanced since the tracer fire itself is unpolarized.

The development of a tracer fire detection filter for use under conditions other than those for the area close to the sun might best be directed towards a compromise similar to the Army's choice of a green polarizing filter. Such an ideal filter is indicated in Figure III. The filter should have high transmission from about 400 to 520, should have strong absorption between 520 and 580 and high transmission thereafter. The filter should contain a polarizing element. It is suggested that the attention of the dye makers of companies interested in developing this type of filter be directed to this report.

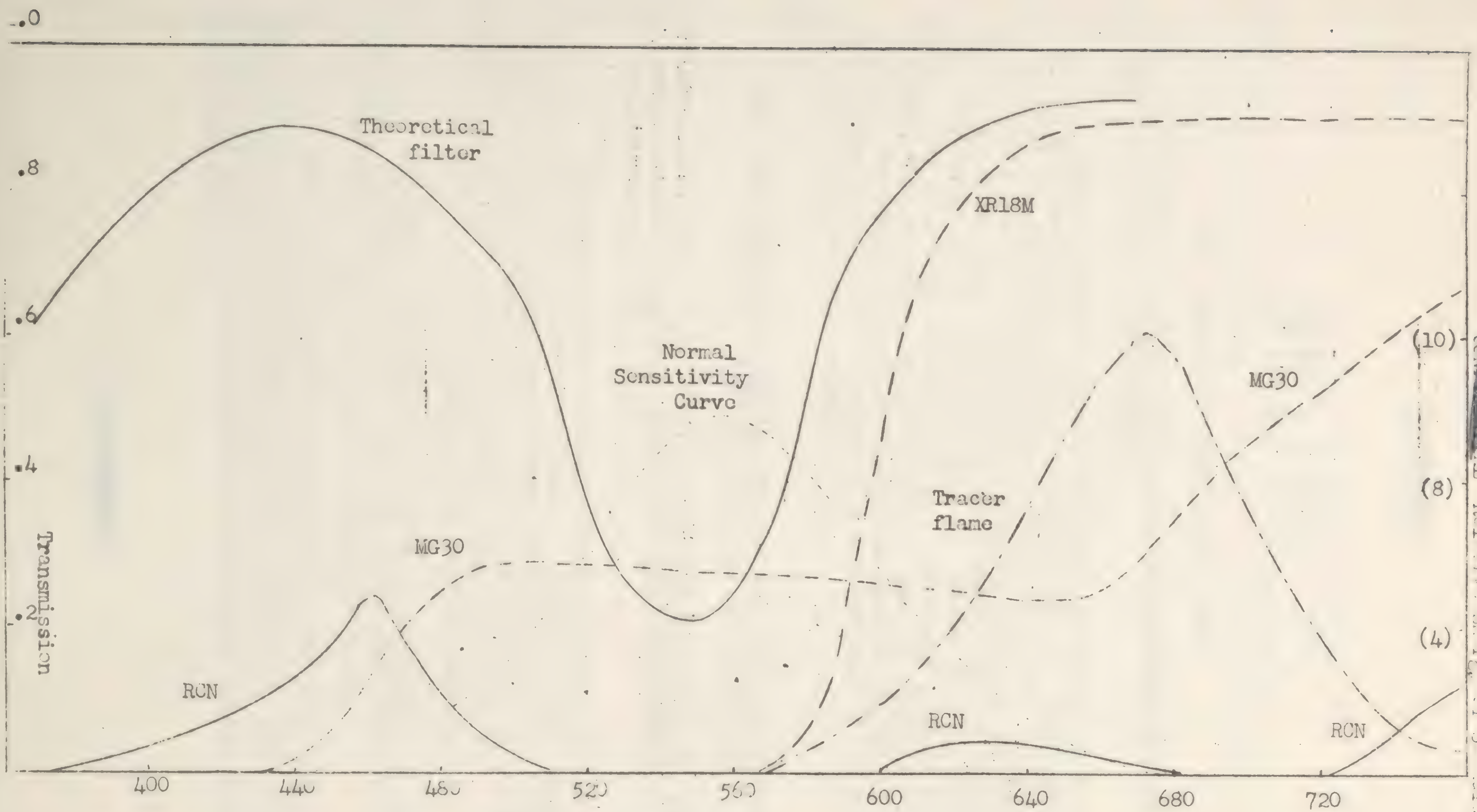

Figure 3 - Tracer Filters

ABSTRACTS

67. AUSTRALIAN VISION CUPOLA (TANK)

Hqs. United States Army Air Forces in the Far East Report No. 208, 1945 February 9, 14pp. (confidential).

Proposed modifications of new all-round vision cupola developed for the tank Matilda as a result of firing trials are described. To counteract the vulnerability of the cupola to small arms fire, the new type has 8 periscopes mounted so that they can be raised and lowered. When lowered, the hole is covered by armor plate. The 8 periscopes are arranged around the periphery and 3 are placed close together so that a very wide range of vision can be obtained with a small head movement. The overall height is no greater than the original Matilda cupola. The report includes detailed description of the cupola and illustrations. A wooden mock-up has been constructed but further development has been discontinued.

68. THE EFFECTS OF CARBON MONOXIDE ON THREE TYPES OF PERFORMANCE, AT SIMULATED ALTITUDES OF 10,000 AND 15,500 FEET

Vollmer, L. P., King, B. G., Fisher, M. B., and Birren, J. E., Naval Medical Research Institute. Research Project X-417, Report No. 7, 1945, February 27, 16pp. (open).

Measurements of the critical flicker frequency threshold, body sway, and the red visual field were made on subjects before, during, and after low pressure chamber runs. Twenty subjects with 12 to 22 per cent carboxy-hemoglobin (COHb) took part in runs at 15,500 feet, and six subjects with 5 to 10 per cent COHb were tested at 10,000 feet. Control runs were made at the same altitudes with the same subjects.

There was a significant impairment of performance at altitude, both under conditions of anoxia alone and anoxia after exposure to carbon monoxide (CO) as compared with performance at sea level.

There was no statistically significant difference between the mean scores of the tests during anoxia alone and during anoxia following administration of CO. Furthermore, the time-performance curves for group means during the hour at altitude are nearly coincident under the two conditions.

69. GERMAN OBSERVATION PERISCOPE (TANK)

U. S. Army. Hqs. Communications Zone European Theater of Operations. Ordnance Technical Intelligence Report No. 154, 1945 February 24, 4pp. (restricted).

A new two-way tank type periscope, recovered from the 8-wheel Armored Car Sd. Kfz. 234/2, enables the vehicle operator to see to the front or rear by pressing a lever which rotates a mirror system. The report includes a detailed description of the one-piece steel body design, the reflecting elements, and the position of the elements for forward and rear observation. Illustrated.

70. INFRARED ABSORBING PLASTIC

Marks, Mortimer. Hqs. Air Technical Service Command. Engineering Division, Aero Medical Laboratory. Memorandum Report TSEAL3C-695-47C, 1945, March 20. (open).

Attempts at the Aero Medical Laboratory to develop plastic lenses for the B-8 goggle which absorb ultraviolet and infrared rays revealed that cupric chloride ($CuCl_2 \cdot 2\ H_2O$) when combined with ethyl silicate ($C_2H_5 \cdot SiO_4$) and a plastic known as Alvar produce a plastic medium having a high visual transmission and almost complete absorption of ultraviolet and infrared. Tests of this plastic composition at the Monsanto Chemical Co. laboratory indicate that it is heat stable and fairly stable to ultraviolet exposure. Manufacturing processes are discussed and service tests of transmission and stability are recommended.

71. EFFECTS OF ANOXIA ON PERFORMANCE AT SEVERAL SIMULATED ALTITUDES

Birren, J. E., Fisher, M. B., Vollmer, E. P., and King, B. G., Naval Medical Research Laboratory. Research Project X-293, Report No. 2, 1945, February 20, 19pp. (open)

Twenty-nine subjects were given "flights" at one or more simulated altitudes, 10,000, 14,000, 15,500, and 18,000 feet, in a low pressure chamber. The subjects were given a cycle of three tests (critical flicker frequency, perimetry of the visual field with a red target, and body sway) once at sea level before "ascent", five times during an hour under the anoxic conditions, and once more immediately upon return to sea level.

The report concludes:

Critical flicker frequency and perimetry can be used to detect changes in performance of small groups of subjects under anoxic conditions (10,000 feet and above). Body sway can be employed to demonstrate differences in performance at 14,000 feet and above. The magnitude of most of these changes is such that individual scores are within the normal distribution of values at sea level and hence cannot be used as criteria of the extent of anoxia in a given individual.

The lack of correlation among performance decrements in the tests suggests considerable variation in the underlying physiological adjustments to anoxia. Hence it would seem desirable to use groups of subjects and several measures of performance requiring various levels of activity when attempting to relate personnel efficiency to anoxic stress.

72. PHYSIOLOGY OF FLIGHT: HUMAN FACTORS IN THE OPERATION OF MILITARY AIRCRAFT

Hqs. Air Technical Service Command. Engineering Division. Aero Medical Laboratory. AAF Manual No. 25-2, 1945, March 15, 94pp. (open).

This manual replaces manual of the same title published in 1942 by Aero Medical Laboratory, Engineering Division, Air Technical Service Command, Wright Field. The introduction states, "An effort is made in (these) pages to outline some of the important factors in the physiological effects of flight and to describe the devices that contribute to the welfare and tactical efficiency of flying personnel.

Chapter VIII on vision contains a general discussion of the relation of the function and anatomy of the eye to problems of sky search and visibility, and, in more detail, to the various aspects of vision at night. Standards for goggle and sun glass lenses and the problem of distortion in aircraft glass are discussed.

73. SMOKE SIGNALS FOR LIFE RAFTS - AERIAL PRODUCTS INC.

Army Air Forces Board, Orlando, Florida. Project 3929D452.16, 1945 February 6, 19pp. (restricted).

In air-to-ground observations over land and water at various altitudes and under varying conditions of viewing, the visual effectiveness of the Aerial Products smoke signal was compared with

that of the M-11 flare and the British "Two-Star Red, Mark II." The visual effectiveness over water of the Aerial Products smoke signal is superior to that of the M-11 flare when the air-to-ground visibility is greater than five miles and inferior at less than five miles. The visual effectiveness over land of both signals is affected by the color of the soil, the density of the vegetation, the season of the year, and the air-to-ground visibility. The smoke signal and the M-11 flare can be safely used within a life raft. The report recommends that:(a) the M-11 flare be made standard in life rafts, for use on days of low visibility, in addition to its present standard night use; (b) the experimental smoke signal be employed on days of good visibility; (c) no consideration be given the British Mark II flare as a signal because it has been superseded by the Mark III; (d) further tests be conducted to determine which of all the flares, smoke signals, fuzes and dyes is the best signal for day and night use. Other advantages of the experimental smoke signal are size (half the size of the M-11) and self-contained operation. The AAF Board concurs in the conclusions and recommendations of the AAF and further recommends that: (a) The Aerial Products smoke signal be made a standard item of emergency equipment; (b) immediate utilization be made of the signal by including one in each C-1 emergency survival vest replacing the 5 minute fusee red flare now a part of the kit; (c) as soon as the requirements for the C-1 vest are met, consideration be given to including this smoke signal in four man life rafts and the "E" series of emergency kits.

Other reports received, which may be secured or consulted in the Office of the Vision Committee:

74. Great Britain. Ministry of Supply. Advisory Council for Scientific Research and Technical Development. Fighting Vehicle Armament Research and Development Committee. Tank Armament Research Report No. 22, 1945, February 20, 21pp.

Study of the optimal value of magnification of telescopes under various conditions of haze, heat shimmer, vibration, and twilight illumination.

75. Great Britain. Ministry of Supply. Advisory Council for Scientific Research and Technical Development. Fighting Vehicle Armament Research and Development Committee. Tank Armament Research Report No. 23, 1945, February 17, 9pp.

Field comparison of two 6X tank telescopes of different field of view.

76. Gt. Britain. Ministry of Home Security. Research and Experiments Department. Report RC(E) 19, 1941, September 9, 51pp.

A detailed summary of present knowledge concerning the scientific basis of screening by smoke, the behavior and properties of smoke, and the assessment and development of smoke producing apparatus.

77. Gt. Britain. Medical Research Council. Military Personnel Research Committee. B.P.C. 44/396/P.L. 157, 1944, December, 8pp.

Measurements were made of the time taken by the gunner and commander to perceive the trace from the 17 pdr. tank gun when firing APC ammunition. The effect of smoke, dust, shimmer, etc. is to increase this minimum time.

78. Australia. Royal Australian Air Force. Flying Personnel Research Committee. F.R.100, 1945, February 15, 3pp.

A device for illuminating the range scale of ASV equipment in order to increase its legibility and reduce operator fatigue is described.

79. Canada. Canadian Army Operational Research Group Report No. 22, 1945, March 9, 34pp.

A summary of fundamental data on the visibility from aircraft of objects on the ground, with tests using achromatic signal panels.

80. Gt. Britain. Ministry of Supply. Council on Scientific Research and Technical Development. Fighting Vehicle Armament Research and Development Committee. Tank Armament Research Report No. 21, 1945, February 15, 8pp.

Study of the effect of atmospheric refraction, due to the vertical temperature gradient near the ground, on accuracy of tank gunnery.

76. Gt. Britain. Ministry of Home Security. Research and Experiments Department. Report RC/IR 12, 1942. September 9, 1942.

A detailed summary of present knowledge concerning the scientific basis of screening by smoke, the behavior and properties of smoke, and the measurement and development of smoke-producing [illegible].

77. Gt. Britain. Medical Research Council. Military Personnel Research Committee. B.P.C. 43/[illegible]. [illegible], December, 1943.

[illegible] were made of the time taken by the [illegible] and [illegible] from the [illegible] during [illegible]. The effect of smoke, [illegible] to increase [illegible].

78. Australia. Royal Australian Air Force. [illegible] Report No. 100, 1943. February 1, 1943.

A method for [illegible] in order to [illegible] the [illegible] and [illegible].

79. Canada. Canadian Army Operational Research Group. Report No. 12, 1945. March 9, 1945.

A summary of [illegible] on the [illegible] of objects on the ground, with tests using [illegible].

80. Gt. Britain. Ministry of Supply. [illegible] Research and Development [illegible] Committee. [illegible] 1943, February 10, 1943.

[illegible] effect of [illegible] on the [illegible].

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